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ELEMENTS
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SCIENCE AND ART:
BEING A
FAMILIAR INTRODUCTION
TO
NATURAL PHILOSOPHY AND CHEMISTRY:
TOGETHER WITH
THEIR APPLICATION TO A VARIETY OF ELEGANT
AND USEFUL ARTS.

BY JOHN IMISON.

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ELEMENTS OF SCIENCE.

CHEMISTRY.

HITHERTO we have considered the action of bodies on each other in masses, or what is called their *mechanical* actions; and for this purpose it was not necessary to attend particularly to the difference in the many species or kinds of matter, which we distinguish more or less readily.

But if we present bodies of different kinds to each other in proper circumstances, a certain action takes place between the minute particles of one sort of substance upon those of another sort, by which, frequently, the individual or peculiar properties of each disappear, and a new substance is formed.

The study of this action of the minute or ultimate particles of different kinds of matter on each other is called *chemistry*, and the powers thus exerted occasion *chemical actions*.

Independently of the enlargement of our views of nature, and the pleasure and entertainment derived from contemplating her operations, chemistry is essentially useful in many of the arts upon which the comforts, and even the very existence, of civilized life, depend.

As examples, we may mention the arts of dyeing, bleaching, tanning, potting, glass-making, baking, brewing, distilling, working metals, &c. &c. which owe their present state of perfection to the science of chemistry In agriculture it is capable of affording great assistance, by explaining the nature of soils and manures; and in medicine its importance is invaluable, many of the most efficacious remedies being entirely formed by chemical processes. In short, there is scarcely any art or trade which either does not altogether depend upon, or may be benefited by this science.

By chemical means we are enabled to reduce *compound bodies* to the constituent principles of which they are composed, and this operation is called *analysis*, or *decomposition*. When a substance cannot by any means be resolved into others, it is called a *simple* body; and it is now known that all that vast variety of substances which we see is composed of a few simple bodies, which hence are called *elementary substances*.

Formerly, *air*, *earth*, *fire*, and *water*, were supposed to be the elements of which all bodies were formed; but modern chemistry has shown that this was an erroneous supposition. For the air, or atmosphere, is compounded of several distinct kinds of aerial fluids or gases. Instead of one kind of earth, it is now known that there are several kinds. Water is no longer considered as an element, being, in fact, formed of two substances very different, *viz.* of oxygen and hydrogen. Fire is less understood, and is still retained as an element under the name of caloric.

From the improvements that are continually making in the methods of analyzing bodies, or separating them into their component principles or elements, several other substances once supposed to be simple are now found to be compounds: and, as chemistry continues to advance, the list of simple substances may be reduced; our inability to decompose any body not proving it to be simple, but only, perhaps, that our methods of examination are still imperfect.

The substances which hitherto have resisted all the known methods of analysis, and which, in the present state of our knowledge, are considered as the elements of all bodies with which we are acquainted, are the following: —

Substances not metallic.

1. Light
2. Caloric
3. Electric fluid
4. Oxygen
5. Nitrogen
6. Hydrogen
7. Chlorine
8. Iodine
9. Sulphur
10. Carbon
11. Phosphorus
12. Boron
13. Fluorine.

Metallic substances.

14. Potassium
15. Sodium
16. Lithium
17. Calcium
18. Magnium
19. Barium
20. Strontium
21. Silicium
22. Aluminum
23. Yttrium
24. Glucinum
25. Zirconium
26. Thorinum
27. Platina
28. Gold
29. Silver
30. Mercury
31. Iron
32. Copper
33. Tin
34. Lead
35. Zinc
36. Antimony
37. Bismuth
38. Arsenic
39. Nickel
40. Manganese
41. Cobalt
42. Molybdena
43. Tungsten
44. Osmium
45. Iridium
46. Rhodium
47. Palladium
48. Cadmium
49. Tellurium
50. Titanium
51. Chromium
52. Uranium
53. Columbium
54. Cerium
55. Selenium.

The utmost degree of mechanical division which we can effect in bodies, by pounding, grinding, and similar processes, can only reduce them to fragments so small that they can no longer be perceived by the sight; but we cannot thus arrive at those ultimate atoms, molecules, or particles, of which the various species of matter are supposed to consist, and which are, perhaps, incapable of subdivision.

Besides the attraction of gravitation possessed in common by all matter, these elementary substances possess peculiar attractions for each other, which are called *chemical attractions*. By these attractions, or *affinities*, as they are called, they combine together, and form *compound bodies*.

OPERATIONS AND INSTRUMENTS USED IN CHEMISTRY.

The great principle of all chemical operations which enable us to decompose certain bodies, and to compound others, is, that *every substance has a peculiar affinity or attraction for other substances, but that it has different degrees of attraction for different substances*. This is called *elective affinity or attraction*.

If some oil and some alkali be put together, they will unite and form soap. But if to this a little dilute sulphuric acid be added, the oil and alkali will be separated from each other again; the alkali having a stronger attraction for the acid than it has for the oil, will leave the latter and join the acid.

Dissolve some magnesia in nitric acid, and the solution will be transparent. Also dissolve some lime in water by letting it remain for some hours: the solution of lime in water will also be transparent. Pour them together, and immediately a turbid appearance will be presented, and a white powder will fall to the bottom. This powder will be found to be magnesia. The explanation is this: the nitric acid has a greater attraction for lime than it has for magnesia; therefore, it lets fall the latter and takes up the former. The substance thus thrown down is called a *precipitate*, and the process is called *precipitation*.

If all the bodies presented to each other are compounds, sometimes two new substances are formed. Thus, if solutions of nitrate of barytes and of sulphate of soda be mixed together, the former being composed of nitric acid and barytes, and the latter of sulphuric acid and soda, two new products will be obtained, *viz.* nitrate of soda and sulphate of barytes. For the nitric acid will leave the barytes and join to the soda, and the sulphuric acid will give up the soda and seize the barytes. This is called *double elective affinity*, as the former example was of *single elective affinity*. When different substances unite *chemically*, and form a compound, they always unite in the same proportion. Thus, water, which is composed of oxygen and hydrogen, always contains the same proportion of each; that is, we do not find that in several specimens of water the proportions of oxygen and hydrogen vary. Also, if an acid and an alkali combine together, and thus form a certain salt, they always unite in the same proportion to form that salt; however, they will sometimes combine in another proportion to form another salt; but when substances unite in more than one proportion, the second, third, &c. proportions are multiples or divisors of the first. This is one of the latest discoveries in chemistry, and has given rise to the doctrine of *definite proportions.*

Here it must be remarked that *chemical combination* and *mechanical mixture* are very different; since, although bodies only *combine* in definite proportions, yet, they can be *mixed* together in all proportions.

In general, before substances can be made to act chemically on each other, one of them, at least, must be in a fluid state; and, that solids may be acted on more easily, they are generally mechanically divided into small pieces, or reduced to a powder.

By *trituration*, *pulverization*, and *levigation*, is meant the reduction of solids into powders of different degrees of fineness. Brittle substances are reduced to powder by means of hammers, pestles and mortars, stones and mullers. *Mortars* and *pestles* are made either of metal, glass, porcelain, marble, agate, &c. according to the hardness and properties of the bodies to be pounded. WEDGEWOOD's ware affords a most excellent kind of mortar for most purposes, as it is very strong, and not liable to be acted upon by acids. Many bodies cannot be reduced to powder by the foregoing methods: such are fibrous substances, as wood, horns of animals, elastic gum, and mettles which flatten under the hammer; for these, *files*, *rasps*, *knives*, and *graters*, are necessary.

The separation of the finer parts of bodies from the coarser which may want farther pulverization, is performed by means of *sifting* or *washing*.

A *sieve* for sifting generally consists of a cylindrical band of thin wood, or metal, having silk, leather, hair, wire, &c. stretched across it. They are of different degrees of fineness.

Washing is used for procuring powders of an uniform fineness, much more accurately than by means of the sieve; but it can only be used for such substances as are not acted upon by the fluid which is used. The powdered substance is mixed with water, or other convenient fluid: the liquor is allowed to settle for a few moments, and is then decanted off; the coarsest powder remains at the bottom of the vessel, and the finer passes over with the liquor. By repeated decantations in this manner, various sediments are obtained, of different degrees of fineness: the last, or that which remains longest suspended in the liquor, being the finest.

Filtration is a finer species of sifting. It is sifting through the pores of paper, or flannel, or fine linen or sand, or pounded glass, or porous stones, and the like; but it is used only for separating fluids from solids, or gross particles that may happen to be suspended in them, and not chemically combined with the fluids. Thus salt water cannot be deprived of its salt by filtration; but muddy water will deposit its mud. No solid, even in the form of powder, will pass through the abovementioned filtering substances: hence if water or other fluid, containing sand, insects, mud, &c. be placed in a bag or hollow vessel made of any of those substances, the sand, &c. will remain upon the filter, and the liquor will pass through, and may be received clear in a vessel under it. Unsized paper is a very convenient substance for making filters for chemical purposes. It is wrapped up in a conical form, and put into a glass funnel, which serves to strengthen the paper and support the weight of the fluid when poured into it.

Decantation is often substituted, instead of filtration, for separating solid particles which are diffused through liquors. These are allowed to settle to the bottom, and the clear fluid is gently poured off. If the sediment be extremely light, and apt to mix again with the fluid, by the slightest motion, a syphon is used for drawing off the clear fluid.

Lixiviation is the separation by means of water, or other fluid, of such substances as are soluble in it, from other substances that are not soluble in it. Thus, if a certain mineral consists of salt and sand, or salt and clay, &c. the given body being broken to powder, is placed in water, which will dissolve the salt, and keep it suspended, whilst the earthy matter falls to the bottom of the vessel, and, by means of filtration, may be separated from the fluid.

Evaporation separates a fluid from a solid, or a more volatile fluid from another which is less volatile.

Simple evaporation is used when the more volatile or fluid substance is not to be preserved. Various degrees of heat are employed for this purpose, according to the nature of the substances. it is performed in vessels of wood, glass, metal, porcelain, &c. Basons made of WEDGEWOOD'S ware are very convenient, as they are not apt to break by sudden changes of heat. Small flasks of thin glass also: these are placed either over the naked fire, or in a vessel filled with sand, which is then called a *sand-bath*. This affords a more regular degree of heat, and renders the vessels less liable to be broken.

When the fluid which is evaporated must be preserved, then the operation is called distillation.

Distillation is evaporating in close vessels, when we wish to separate two fluids of different degrees of volatility, and to preserve the most volatile, or both of them. The substance to be subjected to distillation is put into some vessel that will resist the action of heat, called a *retort*, an *alembic*, or a *still*, having a beak or neck projecting from it, to which is attached another vessel, to receive the fluid that rises first, which is called the *recipient*, or *receiver*. The vessel that contains the liquor to be distilled is placed upon the fire, or in a sand-bath, or over a lamp: the heat causes the most volatile fluid to rise in the form of vapour, and to pass into the receiver, where it is again condensed by cold. This condensation is sometimes assisted by making the vapour pass through a tube which is immersed in a vessel containing cold water.

A (Plate 1. fig. 1.), represents a retort used for distillation. It is a vessel, either of glass or baked earth, for containing the liquid to be distilled. When it has a small neck, *a*, with a stopple fitted to it, for introducing the materials through, it is called a *tubulated retort*. B is the receiver for condensing the vapour which is raised, and into which the neck of the retort is inserted. The joining, *b*, is made air-tight by means of some substance applied to it, called a *lute*. Various methods are used for supporting both the retort and receiver, according to the degree of heat employed in the process, and several other circumstances.

When great heat is employed, earthen retorts are used, which are placed on or in the fire. When a less heat is wanted, glass retorts are generally employed, which must not not be placed immediately on the fire, unless they are coated over with a composition of clay and sand, which is sometimes done. Glass retorts are generally placed in a sand-bath, or suspended over a lamp, for which ARGAND's lamp is the best. The receiver is placed upon some stand convenient for the purpose, with a ring made of hay under it, or some such contrivance, to keep it steady.

A (Fig. 2.), is a vessel called a *mattrass*, for the same purpose, having a vessel, B, called an *alembic*, fitted to the head. The liquid raised by heat into the state of vapour, is condensed in the alembic, and falls into a groove all round its inside, from whence it runs out by the spout, C, into the receiver, D.

Fig. 3. are conical tubes that fit into another, for lengthening the necks of retorts, &c. to connect them with the receivers at any distance: they are called *adopters*.

Fig. 4. are phials with bent glass tubes fitted in them, for disengaging gases, and similar experiments: they were used by PRIESTLEY, and are hence called *Priestley's bottles*, and sometimes *proofs*: they are either tubulated or plain.

A (Fig. 5.), represents a *common still*. It is a large vessel of copper, into which the materials to be distilled are put. The still is built up in brick-work, which covers it up to the neck; the fire is applied underneath, and runs round it in a spiral manner. B is the *head* of the still. This head is connected with the *worm*, which is a spiral tube, immersed in a vessel of cold water, called the *refrigeratory*, or *cooling tube*, C. The liquor being condensed in its passage through the worm, runs out at the cock, D, into the vessel placed there to receive it.

This is the construction of the common still for distilling spirituous liquors; but a very great improvement has been made upon this instrument, in Scotland, within these few years. This improved apparatus is known by the name of the Scotch still, a section of which is represented, Fig. 6. The principle of the improvement consists in exposing a great quantity of the surface of the fluid to the action of the fire, and affording a more ready means for the escape of the vapour or gas.

A, is the body of the still, made very shallow and concave at the bottom, in order that the fire may act better upon it; *bb*, are a number of tubes opening into the still, and communicating with the neck of the still B, in order to convey the vapour off as soon as it is formed; *cc*, is a cover that shuts down over the pipes and top of the still, to keep it warm, by preventing the loss of heat which would be occasioned by the contact of the cold air. This is effected by the quantity of air that is confined between the cover and the top of the still; for it is a fact which is now well known, that *confined* air is a *non-conductor* of heat. In general, the heads of stills are kept warm by laying blankets upon them, at least when this is attended to, as it ought always to be; but this metallic covering, by surrounding the still with a quantity of confined air, answers the purpose still better.

When the materials which are evaporated concrete in a solid form, within the neck of the distilling vessels, then the distillation is more properly called *sublimation*.

By the above means, one fluid may be separated from other materials; but it often happens, that in distillation the substances which are subjected to this process have a chemical action upon each other; new combinations take place, and permanently elastic fluids or gases are disengaged, which are required to be preserved and examined. For this purpose, a very useful apparatus is employed, called the

PNEUMATO-CHEMICAL APPARATUS.

Fig. 7, represents an improved pneumato-chemical apparatus and lamp-furnace connected with it.

A, is a vessel filled with water. In this vessel a shelf is placed, so as to be a little under the surface of the fluid, having several holes bored through it, to which small funnels are attached underneath.

The glass air-jar, or receiver, B, which is to receive and contain the gas, is filled with water, and being inverted with its mouth under water, it is raised up gently till its mouth is nearly out of the water, but not quite; and it is then placed upon the shelf over one of the holes. The receiver will remain full of water, which is kept up by the pressure of the atmosphere upon the principle of the barometer described under pneumatics.

The materials from which the gas is to be disengaged, are now to be put into a glass retort, C, which is put through, and suspended in one of the rings of the lamp-furnace, D. An improved ARGAND's lamp, E, having *two concentric wicks*,* affords a much greater degree of heat than the common ARGAND's lamp, which has only a *single circular wick;* this is placed upon the shelf, F.

---

* This lamp with *two concentric wicks* was first contrived by the editor some years ago, and is extremely useful in some chemical operations, as it gives a much greater heat than the common Argand's lamp with *one* circular wick.

The shelf, with the lamp and the ring having the retort in it, are now to be adjusted by moving them up or down, until the lamp is at a convenient height below the retort, the neck of which rests upon the edge of the cistern, and the end of its neck opens in the funnel under the jar standing upon the shelf. The lamp must now be lighted, and as soon as the substances in the retort act upon each other sufficiently, the gas will begin to be disengaged, and will ascend through the hole in the shelf into the vessel, B, and displace the water with which it had been filled. When all the water is displaced, the receiver is full of the gas which was disengaged from the retort, and may be preserved in it by keeping its mouth always under the water in the cistern.

This gas may be transferred from the vessel, B, into any other vessel, in the following manner: fill the vessel into which the gas is to be transferred, with the fluid in the trough, and place it on the shelf as before directed, over one of the holes. Then take the vessel, B, and keeping its mouth still under the fluid, bring it under the hole on which the vessel is placed, then depressing its bottom, and elevating its mouth, so as to bring it more to a horizontal position, the gas in it will escape and rise up through the hole on which the other vessel has been placed, and will fill it by displacing the fluid. In this manner any gas may be formed, or transferred from one vessel to another.

The cistern for the water may be made of wood, in the manner of a tub, and hooped round, which may or may not be painted inside and out. But it will be much more elegant if made of sheet-iron, tinned, and japanned of a brown or chocolate colour. The ornaments, if any, may be of brass, or gilt. The best material for the lamp-furnace is brass lackered, and the lamp should be of tin japanned. The apparatus constructed in this manner has an extremely elegant appearance, and is found to answer perfectly well for a variety of chemical operations.

When the gas to be procured is absorbable by water, quicksilver is used instead of water; and, as it is very expensive, a smaller vessel is necessary, which must be made of some material not acted upon by quicksilver, as wood or stone; and it must be sufficiently strong to resist the great weight and pressure of the quicksilver. It is usually cut out of a solid block of wood, or marble, or made very strong of mahogany, and varnished over, to make it perfectly tight.

A small glass vessel, capable of containing an ounce measure, is used for measuring gases; for if this phial be successively filled, and inverted under a large jar, we may thereby throw into that jar any required quantity of an elastic fluid, or as many measures of one elastic fluid, and as many of another, as we please.

G (Fig. 7.), represents a tube for receiving a mixture of gases that are to be exploded by the electric spark. It is a very strong glass tube, closed at one end, and having a scale upon it, cut with a diamond. Near the closed end two wires pass through the glass, and almost touch each other, but *not quite;* they are cemented in, so as to make the holes air-tight. When this graduated tube is filled with the fluid in the trough, and inverted upon the shelf, certain measures of the gases to be exploded are introduced in the usual way. If thus the interval between the two wires be made a part of the electric circuit, by fastening chains connected with a Leyden phial to the rings of the wires, the spark will pass through the interrupted space between the two wires, and explode the gases. These instruments are called *exploding tubes.*

In compound distillations, or when a decomposition of the materials subjected to this process takes place, and gases are formed, some of which are absorbable by water, some by alkalis, and others are not capable of being absorbed at all, it is often required to preserve separate the several new substances procured. The apparatus invented by Lavoisier for this purpose is the most convenient.

A (Plate 2. fig. 1.), is a glass retort, the beak of which is adjusted to a double tubulated balloon, or receiver, B. To the upper tubulure of this receiver is fitted a glass tube, C, the other extremity of which is conveyed into the liquor contained in the glass vessel, D: with this vessel, D, which has three tubulures, are connected two or three other similar vessels, by means of glass tubes fitted into their tubulures, and to the last tubulure of the range of vessels is adapted a glass tube which is conveyed under a receiver placed upon the shelf of the pneumatic cistern. Water is put into the first of these vessels, caustic potash into the next, or such other substances as are necessary for absorbing the gases, and the joinings are well luted. Sometimes it will happen that a re-absorption of gas takes place; and in this case, that there may be no danger of the water in the pneumatic tub entering rapidly into the vessels through the tube, E, a capillary tube is adapted to the middle tubulure of each vessel, which goes into the liquid contained in it. If absorption takes place, either in the retort or vessels, the external air enters through these tubes, to fill the vacuum which is occasioned by the absorption, and no water comes into the vessels.

Large vessels for containing air, and expelling any given quantity, are called *gazometers.* They are of various constructions; one of the best is the following: AB (fig. 2.), is a cylindrical vessel of tin, japanned, nearly filled with water, and having a tube, C, in the middle, open at top, and branching, to communicate with the cock, D. Within this vessel there is another cylindrical vessel, generally of glass, of smaller size, F, open at bottom, which is inverted and suspended by the lines *e e*, which go over the pullies *f*, *f*, *f*, *f*, and have weights *g g*, attached to them, to balance the vessel, F. While the cock D remains shut, if the vessel F be pressed downwards, the air included within it will remain in the same situation, on the principle of the diving-bell; but if the cock be opened, and the vessel, F, be pressed down, the air included within it will escape through the cock, and if a blow-pipe be attached to this cock, a stream of the gas may be thrown upon lighted charcoal, or any other body. By means of the graduated rod, *h*, also, the quantity thrown out is exactly ascertained: this rod is so divided as to express the contents of the inner vessel in cubic feet, &c. This instrument also answers for breathing any of the gases, by applying a mouth-piece to the cock. To render it more portable, the weights *g g*, are sometimes included in the uprights *i i*, which are hollow, and wide enough to receive them. Sometimes, also, there is another branch from the bottom of the pipe, in the middle, directed to the side of the outer cylinder, and coming upwards by the side to the top, where there is another cock attached.

For *solution*, and *dissolutions*, and for *crystallizing salts*, vessels of glass or earthenware are used.

The melting, or causing any body to pass from the solid to the liquid state, by the action of fire, is called *fusion*. The fusion of metallic substances requires vessels sufficiently strong to resist the fire. Those vessels are mostly, if not always, made of earthen-ware, or porcelain, or a mixture of clay and powder of black-lead. They are called *crucibles*, and are generally of the forms represented Fig. 3. Sometimes these vessels have covers made of earthen-ware; but sometimes the fused metal must be exposed to a current of air: in that case, the crucibles are broad and shallow, as at Fig. 4. these are called *cupels*, and they are formed of calcined bones, mixed with a small quantity of clay, or of a mixture of clay and black-lead powder. But the cupels must not be placed in a closed furnace, or be surrounded by coals; for, in that case, the required current of air could not have access to the fused metal. They are, therefore, placed under a sort of oven of earthen-ware, which is called a *muffle*, as represented, Fig. 5, which, with the included cupel, is exposed to the heat of a furnace.

The various degrees of heat which are required for the performance of chemical operations render a variety of fire-places, or *furnaces*, necessary for a chemist. Those furnaces are either open at top, or they are covered with what is called a *dome*, and have a chimney, or tube, to carry off the heated air, smoke, &c. They are sometimes supplied with air from the natural action of the fire, which rarefies the air about the ignited fuel; and the rarefied air becoming specifically lighter, ascends into the chimney, whilst the colder, and consequently heavier air, is forced by the atmosphere to enter at the lower part of the furnace. Some furnaces are supplied with air by means of bellows; and those are applied for forging iron, or for reducing metals from the ore, which is called *smelting*. Hence the furnaces derive their various names, and are called *simple*, or *open furnaces, reverberatory furnaces, wind*, or *air furnaces, blast furnaces, forges, smelting furnaces*, &c.

A very useful kind of furnace, for many purposes, is that invented by Dr. Black, of Edinburgh, represented in Fig. 6. It consists of a cylindrical or elliptical body of sheet-iron, coated within with a mixture of loam and clay. The aperture A at top is closed occasionally with an iron saucer full of sand, which forms a sand-bath; B is the door of the fire-place, and C is the ash-pit register, which slides so as to admit more or less air. D is an iron tube which goes into the chimney of the room, to carry off the smoke.

Blow-pipes are used for directing the flame of a candle or lamp against any bit of ore or other substance required to be examined. They ought to have a bulb upon the middle of their stem, to contain the moisture that is formed from the breath. See Fig. 7.

The blow-pipe contrived by Dr. Black, of a conical form, represented in Fig. 8., is very convenient; *a*, is the nozzle.

When a solid substance, in powder or otherwise, is left for a certain time in a fluid, and the mixture is kept exposed to a slow degree of heat, the process is called *digestion.*

When one substance, which has an affinity to another, is mixed with as much of that other substance as its affinity will enable it to hold in combination, then the former substance is said to be *saturated,* or the mixture to have attained the point of *saturation.* If the mixture contain a greater proportion of either substance, then that mixture is said to contain an *excess* of it, or to be *surcharged.* The same thing must be understood of the compounds of more than two substances.

The *dry way* of performing chemical operations is when strong degrees of heat are used, and the *humid way* is when fluid solvents are used.

Combustion is when a body is burned with the assistance of respirable air.

Deflagration is when the combustion is attended with little explosions or cracklings.

Detonation is a pretty loud report.

OF THE NOMENCLATURE OF CHEMISTRY.

One of the chief improvements which have been made in modern chemistry has been the invention of names for the compound substances, which express the elements which enter into their composition, as well as the proportions in which those elements are combined. By this the memory is much assisted, in recollecting the nature of the great variety of substances, and to which the ancient chemists gave arbitrary and frequently unappropriate appellations.

When the simple substances, oxygen, chlorine, and iodine, which are supporters of combustion, enter into combination with each other, or with the other elementary bodies, they form combinations that are divided into two classes. In one class the substances are *not acid*, and their names have their termination in *ide*, as *oxide* of chlorine, *oxide* of nitrogen, *chloride* of sulphur, *iodide* of iron, &c. When these supporters of combustion enter into combination with a body in more than one proportion forming oxides, the terminations, *ous* and *ic*, are employed. Thus nitrogen, with the smallest proportion of oxygen, forms the *nitrous* oxide; and, with a large proportion, it makes the *nitric* oxide.

When the metals combine with oxygen in one proportion only, the compounds are called simply *oxides* of the metals. Formerly the compound of a metal with oxygen was called a *calx*, as the calx of tin, now the oxide of tin; and the process of combining a metal with oxygen was called *calcination*, now *oxigenation.*

Sometimes oxygen can enter into combination with a metal so as to form oxides in more than one proportion, and then a syllable is prefixed to the term oxide to denote that proportion; the smallest quantity of oxygen forms the *protoxide* of the metal, the second quantity of oxygen makes the *deutoxide*, and the third, the *tritoxide;* and, farther, the term *peroxide* is applied to that oxide of the metal that contains the greatest proportion of oxygen with which it is known to combine. The same syllables are prefixed to chlorides and iodides.

An oxide combined with water is called a *hydrat.*

When an *acid* is formed by the union of a simple body with oxygen, it derives its name from that body; as the sulphuric acid, which is formed of sulphur and oxygen; the carbonic acid, which is formed of carbon and oxygen.

Sometimes oxygen will unite in several proportions with a simple body, so as to form different acids; then the acid which is the most oxygenated, has its termination in *ic;* and that which is the least oxygenated, in *ous*. Thus sulphur forms two acids; when it unites to the least proportion of oxygen capable of making an acid, it forms the *sulphureous acid,* and with a larger proportion of oxygen it makes the *sulphuric acid.*

Hydrogen, like oxygen, combines with a certain number of simple substances, and with them forms compounds, some of which are acid, and others are not. To distinguish the *acids formed by hydrogen,* from those formed by oxygen, the former are designated by the word *hydro,* as the *hydro-chloric acid, hydro-fluoric acid.*

Products *not acid, formed by hydrogen* and a simple substance, if solid, are called *hydruret:* if gaseous, the name of the simple substance terminated in *ed* is prefixed to that of hydrogen gas; as *carburetted,* or *phosphoretted hydrogen gas.*

When chlorine, sulphur, phosphorus, and carbon, unite to each other, or to another simple body, the compound has also its termination in *uret,* as chloruret of phosphorus, and of iron, sulphuret of iodine, phosphuret of lime, carburet of iron, &c. *Neutral salts,* or substances produced by the union of acids and alkalis, are denominated from the names of the acids and alkalis of which they are composed. The salts produced by the acid whose names end in *ous* have their terminations in *ite;* thus sulphurous acid and potash form *sulphite* of potash: salts produced by acids ending in *ic* have their termination in *ate:* thus sulphuric acid and potash form *sulphate* of potash, and so of all the rest.

The terms, bi-sulphuret, bi-phosphoret, bi-sulphate, &c. denote that these compounds contain twice as much sulphur, phosphorus, sulphuric acid, &c. as the sulphuret, phosphoret, sulphate, &c.

CALORIC.

Caloric, or the matter of heat, is generally considered as a peculiar elementary substance. It cannot be ascertained to have any weight, a body when heated not being heavier than before.

A distinction is made between *caloric*, or the matter of heat, and the word *heat* when considered as a *sensation*. The sensation of heat, or *sensible heat*, is the effect produced upon our organs by the motion of caloric disengaged from the surrounding bodies. When we touch a cold substance, the caloric, which exists in unequal quantities in different bodies, but which always tends to be in equilibrio in all bodies, passes out of the hand into the body, which feels cold, because at the time there was less free caloric in the substance than in the hand; and as we have lost heat, we feel the sensation of cold: cold being, not any thing positive, but merely the want of heat. The contrary happens when we touch a warm body; the caloric then in passing into the hand, gives the sensation of warmth. If the hand and the body touched be of the same temperature, or very nearly so, we receive no impression either of heat or cold, because there is no motion of caloric.

By *free caloric*, we mean that which is not combined with any other body. But, as caloric has a very strong tendency to combination, we are not able to procure it in that state.

Combined caloric is that which is fixed in bodies by affinity or elective attraction, so as to form part of their constitution. By the expression *specific caloric* of bodies, we understand the respective quantities of caloric requisite for raising bodies of the same weight to an equal degree of temperature. This proportional quantity of caloric is thought to depend upon the distance between the constituent particles of bodies, and their greater or less degrees of cohesion; and this distance, or rather the space or void resulting from it, is called the *capacity of bodies for heat.*

Heat has the property of expanding bodies, or increasing their bulk. This may be observed by fitting a piece of iron to an iron ring so as just to fill it: then if the iron be heated in the fire, it will be found that it has become too large to pass through the ring; but when cooled, it contracts to the same size as before. Some metals will expand more than others.

It is supposed that the caloric forces itself between the particles of bodies so as to separate them. In acting thus, it is in direct opposition to the attraction of cohesion, which keeps them together.

Fluids also expand by heat. Put water into a very small glass tube with a bulb, and apply heat to the bulb; the water will be seen to expand and fill more of the tube: as it cools, it will contract again.

Gases also increase in volume, by increase of temperature. Tie the neck of a bladder tight; when it is almost empty, lay it before the fire; the included air will expand, and the bladder will swell and appear full, but will return to its former state by withdrawing it from the fire. From this property of matter in expanding by heat, the *thermometer* becomes a measure of the heat in bodies.

Every body, therefore, whether solid, liquid, or gaseous, is augmented in all its dimensions, by an increase of sensible heat: and on the contrary, all bodies contract by an abstraction of caloric. We are still very far from being able to produce the degree of absolute cold, or total deprivation of heat; hence, we are incapable of causing the ultimate particles of bodies to touch each other.

It may be supposed, since the particles of bodies are thus constantly impelled by heat to separate from each other, that they would have no connexion between themselves; and that, of consequence, there could be no solid body, unless the particles were held together by some power which tended to unite them: this power is the attraction of cohesion. Thus, the particles of all bodies may be considered as subject to the action of two opposite powers, *repulsion* and *attraction*, between which they remain in equilibrio. So long as the attractive force remains strongest, the body must continue in a state of solidity; but if, on the contrary, heat has so far removed these particles from each other, as to place them beyond the sphere of attraction, they lose the cohesion they had before with each other, and the body ceases to be solid.

Water gives us a regular and constant example of these facts. Whilst below 32° it remains solid, and is called *ice*. Above that degree of temperature, its particles being no longer held together by reciprocal attraction, it becomes liquid; and when we raise its temperature above 212°, its particles giving way to repulsion caused by the heat, assume the state of *vapour* or *gas*, and the water is changed into an aeriform fluid.

The same may be affirmed of all bodies in nature. They are either solid, or liquid, or in the state of elastic aeriform vapour, according to the proportion which takes place between the attractive force inherent in their particles, and the repulsive power of heat acting on them; or, what amounts to the same thing, in proportion to the degrees of heat to which they are exposed. But were there no other cause affecting the solidity of bodies except the powers of attraction and repulsion, they would become liquid at an indivisible degree of the thermometer, and would almost instantaneously pass from the solid state of aggregation to that of aeriform elasticity. Thus water, for instance, at the very instant when it ceases to be ice, would begin to boil, and would be transformed into an aeriform fluid, having its particles scattered indefinitely through the surrounding space. That this does not happen, must depend upon the action of some third power. The pressure of the atmosphere prevents this separation, and causes the water to remain in the liquid state until raised to the temperature indicated by 212°; the quantities of caloric, which it receives in the lower temperatures, being insufficient to overcome the pressure of the atmosphere.

Whence it appears, that, without this atmospheric pressure, we should not have any permanent liquid, and should only see bodies in that state in the very instant of melting; for the smallest addition of caloric would then instantly separate the particles, and dissipate them through the surrounding medium. Besides, without this atmospheric pressure, we should not even have any proper aeriform fluids; because the force of attraction would be overcome by the repulsive power of caloric; and the particles of bodies would separate themselves indefinitely, having nothing to give limits to their expansion, unless their own gravity might collect them together so as to form an atmosphere.

It may be admitted, therefore, as a general principle, that almost every body in nature is susceptible of three several states of existence, *solid*, *liquid*, and *aeriform*; and that these states depend upon the quantity of caloric combined with the body.

The elastic aeriform fluids are expressed by the generic name of *gas*; and in each species of gas, a distinction is made between the caloric, which, in some measure, serves the purpose of a solvent, and the substance which, in combination with the caloric, forms the base of the gas. Thus water, united to a sufficient quantity of caloric, is called *aqueous gas*; ammoniac saturated with caloric, is called *ammoniacal gas*, &c.

Caloric, when free, appears to move in the form of rays, and to be capable of being reflected in the same manner as light. The calorific part of the solar rays, or those which occasion heat, are condensed by a lens, or a mirror, as well as those which produce light; and the rays of heat from any burning body, or even of a body heated, although not in a state of combustion, are thrown off in a radiating manner. If two polished metallic mirrors be placed opposite to each other, at several feet distance, and if a pan of burning coals, or a heated piece of iron, be held in the focus of one of them, a thermometer placed in the focus of the opposite one, will be immediately affected as if it had been held close to the heated matter; and this will be the case, even if the heated body is not luminous or incandescent, as hot water, for instance; so that the invisible rays of heat also are reflected like those of light. The chief part of the heat received from a common fire is in the form of radiant heat; and whatever kind of construction will most promote the reflection of radiant heat into the room, will be the most advantageous form of the chimney. It is upon this principle that the grates introduced into common use by Count Rumford are so much preferable to all others.

The effect of the solar rays upon bodies differs much according to their colour; black and dark coloured bodies are more heated than white ones; the latter throwing off the rays, while the former absorb them. For this reason, black clothes are more heated by the sun than white ones. Polished surfaces, also, which reflect best, do not absorb so much heat as rough surfaces.

The *boiling* or *ebullition* of liquids is a phenomenon which depends upon the liquid being converted into vapour by a certain degree of temperature; consequently, those liquids which assume the vaporous or aeriform state at the lowest temperature are most easily made to boil. The ebullition, or the noise and motion of the liquid in boiling, is occasioned by small quantities of vapour being formed at the bottom of the vessel, which rise by their lightness in a globular form, and break at the surface. The ebullition of liquids is easier in proportion as the pressure to which they are subjected is less; thus water, which boils only at 212° Fahr. in the air, will boil with a much less degree of heat in an exhausted receiver of the air pump; and it will also boil with much less heat on lofty mountains than in the valleys.

Bodies differ very much with respect to the facility with which heat passes through them. Those which transmit caloric easily are called *conductors* of caloric; and, according to the power of doing so, they are termed good or bad conductors. Those which do not transmit heat at all, or with great difficulty, are called *non-conductors*. However, it should be observed, that, perhaps, no substances are absolutely non-conductors; but liquids and gases admit the passage of caloric through them with such great difficulty, that, for practical purposes, this division is found useful. Liquids carry heat chiefly by transportation; the part of the liquid that is heated rises to the surface, and gives place to another which is warmed in its turn, and so on until the whole has been heated.

Many very important applications of this principle have been made by Count Rumford to œconomical purposes. He showed that a stratum of confined air was one of the best modes of preventing the escape of heat.

The best conductors of heat are metals, and the best non-conductors are fluids and porous substances. Charcoal is an excellent non-conductor.

Heat may be excited by mere friction; and this, probably, was the earliest mode of obtaining it to procure fire. It is still practised among uncivilized nations. For this purpose they take two pieces of dry wood, one about eight or nine inches long, and the other piece quite flat. They cut a blunt point upon the first, and, pressing it upon the other, they whirl it round very quickly, holding it between both their hands, as we do a chocolate mill. In a few minutes the wood takes fire. If the irons of the axle of a coach-wheel be left without grease or oil, they will become so hot as to set fire to the wheels; and accidents of this kind sometimes happen.

It is no uncommon practice in the country, for a blacksmith to hammer a piece of iron till it becomes red hot, as a substitute for a tinder-box. The heat excited by the boring of a cannon is sufficient to cause water to boil.

Heat is also produced by collision; when a piece of hardened steel is struck with a flint, some particles of the metal are broken off, and so violent is the heat produced by the stroke, that they are rendered red hot, and melted. If the fragments of steel be caught upon a piece of white paper and examined with a microscope, they will be found to be spherules, and highly polished, showing that they had been fluid.

No heat seems to follow from the percussion of liquids in soft bodies.

The instruments for measuring heat by the expansion of bodies are, *thermometers* for fluids, and *pyrometers* for solids.

A thermometer is a hollow tube of glass, hermetically sealed, and blown at one end into the shape of a hollow globe, or bulb. The bulb and part of the tube are filled with mercury, which is the only fluid that expands equally. When we immerse the bulb of the thermometer in a hot fluid, the mercury expands, and, of course, rises in the tube; but when we plunge it into a cold body, the mercury contracts, and, of course, *falls* in the tube. The rising of the mercury, therefore, indicates an increase of heat; its falling, a diminution of heat.

To facilitate the observation, the tube is divided into a number of equal parts, called degrees, or there is a divided scale attached to it.

This scale is graduated in different manners by different nations: Fahrenheit's scale is that always used in this country.

The standard points are obtained by freezing and boiling water, degrees of heat which are constantly the same in nature. The heat at which the mercury stands, when immersed in each, being marked, the distance between them is divided into 180 parts, and 32 parts of the same size are continued downwards, so that 32° shows the heat of freezing water, and 212° that of boiling water. Water cannot be made hotter than this in open vessels, because it then becomes converted into *steam*, or *aqueous* gas.

The mercurial thermometer, it is evident, cannot measure degrees of heat above that of boiling mercury, nor below that of freezing mercury; the former is 600°, and the latter 40° below 0 of Fahrenheit's scale.

For greater degrees of cold, thermometers of spirits of wine, or essential oil, are used; and to measure those higher degrees of heat to which the thermometer cannot be applied, *pyrometers* are employed. An instrument of this kind was invented by the late Mr. Wedgewood. It consists of two pieces of brass, fixed so as to form an angle, having the legs divided into equal parts. Pieces of baked clay are prepared for this scale, so as to fit the brass at a certain place. If then the piece of clay be exposed to the heat required to be examined, it will contract in its dimensions, and, when again applied to the brass scale, it will be seen how much it has contracted. By this the intensity of the heat is ascertained, for the clay of which these pieces are prepared, has the property of contracting regularly, according to the degree of heat.

This is an exception to the general law of bodies expanding by heat; the expansion of melted metal in the act of cooling is another, as likewise the expansion of water in the act of freezing.

The greatest degrees of heat which can be raised have been produced by concentrating the solar rays with a mirror or lens, or by supplying a blowpipe with oxygen gas; or, what is still more powerful, by a mixture of oxygen and hydrogen. This last method has been but lately employed, and produces a far greater degree of heat than any other. The mixture is itself of an explosive nature, and, therefore, without proper precaution, exceedingly dangerous. The greatest degree of cold known to have been produced has been obtained by mixing snow with certain salts. The best salt for this purpose is muriat of lime. If this be mixed with dry light snow, and stirred well together, the cold produced will be so intense as to freeze mercury in a few minutes. Salt and snow also produce a great degree of cold.

Evaporation, likewise, produces cold. The method of making ice artificially in the East Indies depends upon this principle. The ice-makers at Benares dig pits in large open plains, the bottom of which they strew with sugar-canes, or dried stems of maize, or Indian corn. Upon this bed they place a number of unglazed pans, made of so porous an earth that the water oozes through their substance. These pans are filled towards evening, in the winter season, with water which has been boiled, and are left in that situation till morning, when more or less ice is found in them, according to the temperature of the air; there being more formed in dry and warm weather than in cloudy weather, though it may be colder to the human body.

Every thing in this operation is calculated to produce cold by evaporation; the beds on which the pans are placed suffer the air to have a free passage to their bottoms, and the pans, constantly oozing out water to their external surface, are cooled by the evaporation of it.

In Spain, they use a kind of earthen jars called buxaros, the earth of which is so porous, being only half baked, that the outside is kept moist by the water which filters through it; and, though placed in the sun, the water in the jar becomes as cold as ice.

It is a common practice in China, to cool wine, or other liquors, by wrapping a wet cloth round the bottle, and hanging it up in the sun. The water in the cloth evaporates, and thus cold is produced.

Ice may be produced, at any time, by the evaporation of ether. Take a thin glass tube, four or five inches long, and about two or three eighths of an inch in diameter, and a two-ounce bottle of ether, having a tube drawn to a point, fitted to its neck. Pour some water into the glass tube, and let a stream of ether fall upon that part of it containing the water, which, by that means, will be converted into ice in a few minutes. If a thin spiral wire be introduced into the tube before the water is poured in, the ice will adhere to it, and may be drawn out.

LIGHT.

Under Optics, the mechanical properties of light were considered.

Light has considerable influence on chemical operations, but little is known of its real nature. Most generally it is considered as a certain simple substance, of which the chief source is the sun; and it is also disengaged during the processes of combustion.

The most delicate experiments have been instituted for the purpose of discovering whether it has weight, but without success; on which account it is reckoned among the imponderable bodies.

There appears to be an intimate connexion between light and heat, and they are frequently given out together. But although they are both always found in the sun's rays, yet from them they may be obtained separately, the invisible rays of heat being more refrangibible than those of light: see vol. i.

Light is capable of entering in union with many substances, and of being again separated from them. This is the case in the substance called pyrophorus, which is made by exposing to a red heat in a crucible for some time, a mixture of pounded oyster shells and sulphur. If this substance be then carried into the light for a few seconds, it will imbibe so much that it will become luminous in the dark by again giving out this light.

Various kinds of meat, but particularly fish when they are beginning to putrefy, also rotten wood, sea-weeds, and some insects, as the glow-worm and lanthorn fly, have the property of shining in the dark.

The effect of light upon vegetation is well known. Many flowers follow the course of the sun, and most flowers turn themselves more or less towards the light. Plants that grow in darkness are pale and without colour, and when this is the case they are said to be *etiolated*, or *blanched*. Gardeners avail themselves of this fact to render some vegetables, as celery and endive, white and tender. The more plants are exposed to the light, the more colour they acquire. Vegetables are not only indebted to light for their colour, but their taste and odour are derived from the same source. From this it happens, that hot climates are the native countries of perfumes, odoriferous fruits, and aromatic resins. The action of light on the organs of vegetables causes them to pour out streams of oxygen gas from the surfaces of their leaves, while exposed to the sun, whereas, on the contrary, when in the dark, they emit air of a noxious quality.

Animal life seems also to be no less influenced by light. Birds that inhabit tropical countries have much brighter plumage than those of the north. Animals in general seem to droop when deprived of light; and no doubt it is very essential to the health of human beings.

The colour of metallic oxides is changed by the action of light: the yellow oxide of tungsten becomes blue by exposure to light; the white salts of silver become black, and green precipitate of iron becomes red. Some oxides of metals lose weight by exposure to light, as the red oxide of mercury; others lose their oxygen entirely, or become reduced, as the oxide of gold. Light, then, has the property of separating oxygen from several of the oxides.

Some substances when heated to a certain degree become luminous; iron, for instance; and this is what is called a *red heat.*

If bodies heated to redness be introduced into a gas, it does not become visible, and hence it has been concluded that gas is not capable of being made luminous: but it is now considered that flame is hydrogen gas in a luminous state.

Light is also produced by percussion; as in the case of a flint and steel. The spark produced in this case is owing to the flint breaking off a small fragment of the steel, which is thus rendered red hot, and burns during its passage through the air. But two pieces of quartz struck smartly together also give out light, although here there can be no combustion.

Instruments for measuring the degree or intensity of light are called *photometers.*

ELECTRICITY.

Electricity and galvanism have been already treated of in the first volume. The electric fluid is now considered as a chemical agent of great importance, exciting a powerful influence in the decomposition of bodies. The connexion between electricity and chemical decomposition was first shown by Sir Humphry Davy, to whom the world is indebted for so many brilliant discoveries.

There is still, however, great uncertainty and various opinions with respect to the real nature of this influence, which is usually classed among the imponderable elementary bodies.

OXYGEN.

Oxygen is an elementary body that cannot be procured in a separate or free state, that is, it cannot be detached from the other bodies with which it is always combined.

Oxygen gas is so called from two Greek words, signifying the *generator of acids*, because it was considered by Lavoisier as the only *acidifying* principle. It has been called also *pure* or *vital air.*

About one fourth of the atmosphere consists of this gas, and it is essential to respiration and animal life. It is the most powerful and general supporter of combustion ; and by its union with other bodies, it forms most of the acids. Oxygen gas may be easily procured by several processes.

1. It is obtained in the greatest purity from oxy-muriate of potash. Put some of this salt into a small glass retort, place the neck under the shelf of the pneumatic trough, and apply the heat of a lamp to the retort. The salts will soon melt and boil, when oxygen gas will come over in great abundance.

2. Black oxide of manganese is usually employed for furnishing this gas, as it affords it at a cheaper rate. Procure an iron retort made for the purpose, fill it with the oxide, fit a conducting tube to it, and place the retort between the bars of a grate which contains a good fire. Keep up the heat until the retort becomes red hot, and the gas will be received in the pneumatic apparatus. Or it may be made from oxide of manganese, put into a glass retort, with half its weight of strong sulphuric

acid. It may be likewise obtained in great quantity from nitrat of potass (salt petre) in an earthen retort exposed to a strong fire; also from the red oxide of lead, heated with or without sulphuric acid.

Having procured a sufficient quantity of this gas in separate vessels, its properties may be easily examined.

It will be found that water does not absorb it; for if some of it be agitated in a small vial half filled with water, and again immersed into the trough, it will not be diminished in quantity; nor will the water rise in an inverted vessel of this gas, if left on the shelf of the trough for a day.

Oxygen gas is eminently calculated to support the combustion of bodies. Plunge a lighted taper fixed to an iron wire, or a lighted splinter of wood, and the combustion will proceed with a splendour much encreased.

The flame of a lamp urged by a stream of oxygen gas, instead of common air, excites a heat more intense than the hottest furnace.

Even the metals which are not easily combustible in common air burn in oxygen gas with great readiness. Iron or steel wire burns in a very striking manner. It should be kindled by having a small bit of wood fastened to the point; the combustion of this will communicate to the steel wire, which will continue to burn. The fused drops of iron that fall down, when examined, will be found to be no longer malleable, but brittle and converted into the *oxide of iron.* The same change will take place when the other metals are burnt in this gas.

If a piece of charcoal, fixed to an iron wire, be lighted by a blow pipe, and put into a jar of oxygen gas, it will burn with a brilliant light, and throw out numerous sparks, exhibiting a very beautiful appearance. Here the combustion produces a combination of the oxygen with the carbon of the charcoal, and the result is *carbonic acid.*

A small bit of phosphorus, put into a copper spoon, burns in this gas with a light intensely bright. It is necessary to inform the young practitioner, that this experiment must be made with great caution. The phosphorus must be cut under water, and the piece employed must not exceed half the size of a small pea. The glass jar, in which the combustion is made, is not unfrequently broken by the heat. The result of this combustion is the *phosphoric acid,* from the combination of the phosphorus with the oxygen.

In all these cases, if the products of the combustions be carefully weighed, it will be found to exceed that of the substances burned, and the oxygen will be diminished, which shows they have absorbed a quantity of the oxygen employed. But this is still further proved, because the oxygen may be extracted from these newly-formed compounds, and the original bodies will be thus made to re-appear.

If the metal potassium, or sodium, be burned in oxygen, they form, by their union with it, the alkalis, potass and soda; so that oxygen is not only an *acidifying,* but an *alkalising principle.*

Oxygen appears to be connected with the cause of the red colour in blood, for if dark coloured blood be put into a phial of oxygen gas and shaken, the blood will assume a bright red colour.

NITROGEN.

Nitrogen gas is so called, because its base forms nitric acid by its union with oxygen. It was by Lavoisier named *azotic gas*, and its base *azote*, from a Greek word signifying *without life*, because it is entirely destructive to animal life.

This, also, though a very abundant principle, cannot be exhibited in a free or uncombined state.

In the state of gas, it forms a considerable part of our atmosphere; in the solid state it enters into the composition of animal and vegetable bodies, nitric acid, and ammonia. It is incapable of supporting combustion or animal life. It is not absorbed by water, and it has no acid properties.

It may be obtained by separating the oxygen from a portion of the atmospheric air; the residue will be nitrogen. This is done by exposing a certain quantity of atmospheric air to sulphuret of potass, which absorbs the oxygen, leaving the nitrogen free.

It may be also obtained by treating muscular flesh, (as lean veal) with nitrous acid in a retort; the flesh is decomposed, and the nitrogen set at liberty.

That it does not maintain combustion, and is fatal to animal life, may be proved by plunging a lighted taper into a vessel filled with this gas, the taper will be immediately extinguished. If a small animal, as a mouse, or a bird, be immersed in it, it immediately dies.

COMBINATIONS OF OXYGEN AND NITROGEN.

Nitrogen and oxygen unite together in four different proportions:

1. Nitrous oxide, in which the oxygen is but half the volume of the nitrogen.

2. Nitric oxide, in which the volumes of oxygen and nitrogen are equal.

3. Nitrous acid, in which the volume of oxygen is twice the volume of nitrogen.

4. Nitric acid, in which the oxygen is two and a half times the volume of nitrogen.

Nitrous oxide. This gaseous compound, called also the *gaseous oxide of nitrogen*, or the *gaseous oxide of azote*, was first discovered by Dr. Priestley; but it is to Sir Humphry Davy that we owe a thorough knowledge of its properties.

Nitrous oxide is a permanent gas. A candle burns in it with a brilliant flame and crackling noise; before its extinction, the white inner flame becomes surrounded with a blue one. Phosphorus introduced into it, in a state of inflammation, burns with increased splendour, as in oxygen gas.

Sulphur, introduced into it when burning with a feeble blue flame, is extinguished; but when in a state of vivid inflammation, it burns with a rose-coloured flame. Lighted charcoal burns in it more brilliantly than in atmospheric air.

Iron wire, with a small piece of wood affixed to it, and introduced inflamed into a vessel filled with this gas, burns rapidly, and throws out bright scintillating sparks.

Nitrous oxide is rapidly absorbed by water that has been boiled, and a quantity of gas equal to rather more than half the bulk of the water may be thus made to disappear; the water acquires a sweetish taste, but its other properties do not differ perceptibly from common water. The whole gas may be expelled again by heat.

It does not change blue vegetable colours. It has a sweet taste, and a faint, but agreeable odour.

This gas explodes with hydrogen, when electric sparks are made to pass through the mixture. Animals, when confined wholly in this gas, give no signs of uneasiness at first; but they soon become restless, and then die.

When it is mingled with atmospheric air, and then received into the lungs, it generates highly pleasurable sensations. The effects it produces on the animal system are very extraordinary; it excites the body to action, and rouses the faculties of the mind, inducing a state of great exhilaration, an irresistible propensity to laughter, a rapid flow of ideas, and unusual vigour and fitness for muscular exertions, in some respects resembling the sensations attendant on intoxication, without any languor or depression of spirits, or disagreeable feelings afterwards; but more generally followed by vigour and a disposition to exertion, which gradually subsides.

This gas is produced when substances having a strong affinity with oxygen are added to nitric acid, or to nitrous gas. It may, therefore, be obtained by various methods, in which nitrous gas or nitric acid is decomposed by bodies capable of attracting the greater part of their oxygen. The most commodious and expeditious, as well as cheapest mode of obtaining it, is by decomposing nitrate of ammonia by heat, in the following manner: put into a glass retort some pure nitrate, and apply to it an Argand's lamp; the salt will soon liquify, and when it begins to boil, gas will be evolved. Increase the heat gradually, till the body and neck of the retort become filled with a milky white vapour. In this state, the temperature of the fused nitrate is between 340° and 480°. After decomposition has proceeded for some minutes, so that the gas, when examined, quickly enlarges the flame of a taper, it may be collected over water. Care should be taken, during the whole process, never to suffer the temperature of the fused nitrate to rise above 500° of Fahrenheit; which may be easily judged of from the density of the vapours in the retort, and from the quick ebullition of the fused nitrate; for if the heat be increased beyond this point, the vapours in the retort acquire a reddish and more transparent appearance, and the fused nitrate begins to rise, and occupy twice the bulk it did before. The nitrous oxide, after its generation, should stand over water for several hours; it is then fit for respiration or other experiments.

The explanation of this process is as follows: Nitrate of ammonia consists of nitric acid and ammonia; nitric acid is composed of nitrous gas and oxygen; and ammonia consists of hydrogen and nitrogen. At a temperature of 480°, the attractions of hydrogen for the nitrogen in the ammonia, and that of nitrous gas for the oxygen of the nitric acid, are diminished; while, on the contrary, the attractions of the hydrogen of the ammonia for the oxygen of the nitric acid, and that of the remaining nitrogen of the ammonia for the nitrous gas of the nitric acid, are increased; hence all the former affinities are broken, and new ones produced; namely, the hydrogen of the ammonia attracts the oxygen of the nitric acid, the result of which is water. The nitrogen of the ammonia now combines with the disengaged nitrous gas, and forms nitrous oxyd.

To experience its effects in breathing it, put about a gallon into a large bladder, or oiled silk bag, having a tube attached to it, of three-fourths of an inch in diameter. First, the common air must be expelled from the lungs, before the tube is received into the mouth, and the nostrils must be accurately closed with the hand. It must then be breathed backwards and forwards into the bag for a few minutes.

Nitric Oxyde is called also *nitrous gas*. This compound of oxygen and nitrogen cannot be obtained by direct combination, but by abstracting from nitric acid a portion of its oxygen, leaving the remainder in such proportion as to constitute nitric oxide.

When pure, it is not acid, and is void of colour. It is incapable of supporting the combustion of most bodies; nevertheless, phosphorus and pyrophorus burn in it. Nitrous gas is made by putting clippings or filings of copper into a retort with nitric acid, diluted with thrice as much water; red fumes will be given out, if the gas is suffered to escape into the air; but if collected in the pneumatic apparatus, the gas is colourless. In this process, the metal attracts the oxygen from the nitric acid, and becomes oxydated; the rest of the acid being deprived of a great portion of its oxygen, can no longer exist as acid; it therefore expands, becomes aëriform, and appears as nitrous gas.

When nitrous gas and oxygen gas are mixed together in a glass vessel, previously exhausted of air, they instantly unite, and form a reddish coloured gas, which has but half the volume of the two gases, and which is highly acid. This new compound is called *nitrous acid gas*.

Nitrous acid gas is very easily absorbed by water, rendering it a green, sour liquid.

When nitrous gas is mixed with atmospheric air, the same red fume appears, from the nitrous gas uniting to the oxygen of the atmosphere, leaving the nitrogen by itself. Hence this gas has been used for measuring the quantity of oxygen gas contained in air, and an instrument for this purpose has been called an *Eudiometer*. A tall glass tube, sealed at one end, is used for this purpose, filled with water, and inverted in the pneumatic apparatus. Send up a certain measure of the air to be examined into this tube, and mark the space which it occupies in the top of the tube. Then add to it a measure of nitrous gas, and observe the degree of diminution. By comparing how much different specimens of air will be diminished by the same quantity of nitrous gas, the relative quantities of oxygen in each may be estimated. This method of analysing atmosphere is not considered as very correct, and other modes are sometimes used, where there are fewer sources of inaccuracy.

Nitrous Acid.

Considerable uncertainty prevails respecting this acid. The yellow coloured fuming acid, to which this name has been given, appears to be only *nitric* acid holding nitrous gas in solution. The nitrous gas may be expelled from it by the application of heat, and then the nitric acid is left colourless.

But if nitrous gas and oxygen gas be mixed together, without the access of water, by introducing them into a vessel previously exhausted of air, an union takes place; the two gases diminish to half the volume, and an acid gas is produced.

This is the *nitrous acid* in a gaseous form. This acid gas is extremely absorbable by water, which is at first rendered green: then, as the absorption goes on, it becomes blue, and, finally, of an orange colour: by adding more water, it may be brought back to the green colour.

If dry nitrate of lead be distilled, an orange-coloured liquid comes over; which is considered as *nitrous acid* nearly pure.

Nitric Acid.

This acid is one of those which have been longest known to chemists. It is so named from nitre, from which it was procured. The corrosive acid called *aqua fortis* is an impure and weak nitric acid: but it was long used before its analysis was known: this we owe to Cavendish.

Nitre, called also *saltpetre*, consists of this acid united with potass, and the process for procuring the acid depends upon decomposing this salt. For this purpose, some substance is added to the nitre that has an attraction for the potass sufficiently strong to overcome that of the nitric acid, and, consequently, to allow it to be expelled by heat. Sulphuric acid is used for this purpose. During its expulsion, however, the nitric acid suffers a partial decomposition; for though it is *nitric* acid that exists in the salt, it is *nitrous* acid that condenses in the receiver in the form of orange fumes. This is the common *nitrous acid of commerce*.

To convert this into nitric acid, another process is necessary. By distillation, nitrous acid gas is driven off, leaving the nitric acid colourless. Or, it is distilled on black oxide of manganese, which gives more oxygen to it.

Nitric acid is extremely *caustic;* that is, acts powerfully upon animal substances. It unites with the alkalis and earths; it oxidates all the metals except gold and platina; it thickens and blackens oils, converting them into a coal, or inflaming them, according to the nature of the oil, and the degree of the concentration of the acid.

The combinations of nitric acid with different bases are called *nitrates.*

When the nitrogen and oxygen gases are mingled together, they form a compound exactly resembling common or atmospheric air.

Atmospheric Air

Is, indeed, essentially composed of these two gases: and its analysis or decomposition has been one of the most interesting discoveries of modern chemistry. It is curious that one of the ingredients of this substance, so necessary to animal life, should, by itself, be highly deleterious.

It has been completely proved, that the air of the atmosphere is a compound body, formed by the mixture of oxygen gas and nitrogen gas. The first is the only one of them that supports combustion; and when combustion takes place in common air, it is this part that unites to the burning body, forming either an oxide or an acid. If mercury be heated in a given quantity of atmospheric air for some time, it will become changed into a red powder, which will weigh more than the mercury; the air will be found to be diminished in quantity, and to be no longer capable of supporting combustion. The reason of this is, that the oxygenous part of the air has united to the metal, and converted it into an oxyde, leaving behind only the nitrogen.

This decomposition of the atmospheric air may be effected more easily by burning phosphorus in it. During the combustion of the phosphorus, it unites to the oxygen, and forms phosphoric acid; the remainder is nitrogen.

The proportion of oxygen gas contained in a given quantity of atmospheric air can be ascertained by various processes. One method is, by inverting a glass tube into a solution of sulphuret of potass. This substance will absorb the oxygen gas, but not the nitrogen; hence the air in the tube will diminish in bulk, and what remains will show the proportion of nitrogen.

It was supposed by modern chemists, until lately, that oxygen was essential to combustion; and that this process was, in all cases, the combination of oxygen with the combustible body; but it has been found, that there are some other substances, as chlorine and iodine, which have also this property of *supporting combustion*: it is, however, the oxygen that acts in all the usual combustions in common air. The heat and light were supposed to be separated from oxygen, the base of the gas, which became fixed in the burned body. At present it is maintained by some, that combustion may be the consequence of intense chemical action, and need not depend upon any particular combination. This subject, however, remains very obscure.

Air, which has been breathed, is found to have lost its oxygen. This principle is retained in the lungs, and is absorbed into the blood: it appears essentially necessary to vitality.

An animal can only live for a limited time in a given portion of air. If a mouse or a bird be confined under a glass that is closed, they will soon die; a candle, also, will burn only a short time. In crowded rooms, where there is not a free circulation of air, the oxygen is diminished by the respiration of so many persons, and the air is rendered unhealthy. The lights, also, are observed to burn dim, and contribute much to exhaust the oxygen. This points out the importance of ventilating all kinds of apartments, but particularly public places.

It has been found that in 100 parts by measure of atmospheric air, there are 21 parts of oxygen gas and 79 of nitrogen gas.

From the property of oxygen as being essential to respiration and animal life, it had been thought that the salubrity of air must depend upon the quantity of oxygen which it contained; but, although the airs of various places have been examined, as that of towns, prisons, the country, tops of hills, the ocean, &c., it appeared that the proportion of oxygen did not sensibly differ in them all. The healthiness of certain airs, therefore, must depend upon some other circumstances.

Although the great mass of the atmosphere is to be considered as consisting of oxygen and hydrogen, yet it contains a small quantity of many other gases, and also water, and a variety of exhalations and substances dissolved in it. It always contains a portion of carbonic acid gas, perhaps 1 part in 1000, for alkalies become effervescent when exposed to it, and lime water acquires a pellicle on being exposed a sufficient time to the action of the air, even upon the highest mountains.

Since the oxygen of the atmosphere is continually abstracted from it by various decomposing processes, it would appear that nature must have some mode of renewing a principle so important. Vegetables have been supposed to perform this office, since they always exhale oxygen gas in the day, and particularly when the sun shines. This circumstance may be easily observed by putting some leaves into an inverted tumbler of water placed in the sun-shine. Minute globules of air will be seen rising from the leaves, which, collected at the top and examined, will be found to be oxygen.

HYDROGEN.

Hydrogen is so called from two Greek words signifying the *generator of water*, because it is one of the constituent principles of this fluid. It is also one of the ingredients of bitumen, of oils, fat, ardent spirits, ether, and of all the proximate component parts of animal and vegetable bodies: it forms a constituent part of all animal and vegetable acids: it is one of the elements of ammonia, and of various compound gases.

It possesses so great an affinity for caloric, that it is impossible to procure it in the concrete or liquid state, independent of combination. Hydrogen united to caloric forms hydrogen gas.

Hydrogen gas is the lightest substance whose weight we are able to to estimate; when in its purest state it is about thirteen times lighter than atmospheric air. It is unfit for respiration; animals, when obliged to breathe in it, die almost instantaneously. It has a peculiar and disagreeable smell.

It is decomposed by living vegetables, and its base is one of the constituents of oil, resin, &c. It is highly inflammable, and burns rapidly when kindled in contact with atmospheric air, or oxygen gas, by means of the electric spark, or by an inflamed body, exhibiting a blue lambent flame. Water absorbs about one thirteenth of its bulk. It dissolves carbon, sulphur, phosphorus, arsenic, and many other bodies. When its basis combines with that of oxygen gas, water is formed, and with nitrogen it forms ammonia.

An easy method of obtaining hydrogen gas consists in subjecting water to the action of a substance which is capable of decomposing this fluid.

For this purpose, let sulphuric acid, diluted with four or five times its weight of water, be poured on iron filings or bits of zinc, in a small retort or glass bottle; as soon as the diluted acid comes in contact with the metal, a violent effervescence takes place, and hydrogen gas escapes, without external heat being applied. It may be collected in the usual manner over water, taking care to let a certain portion escape, on account of the common air contained in the disengaging vessel.

Hydrogen gas is often found in great abundance in mines and coal-pits, where it is sometimes generated, and becomes mixed with the atmospheric air of these subterraneous cavities. If a lighted candle be brought into this mixture, it explodes, and produces the most dreadful effects. It is called by miners the *fire damp*. It generally forms a cloud in the upper part of the mine, on account of its lightness, but does not mix there with atmospheric air, unless some agitation takes place. The miners frequently set fire to it with a candle, laying, at the same time on their faces, to escape the violence of the shock. An easier and safer method of clearing the mine is, by leading a long tube through the shaft of it to the ash-pit of a furnace; by this means the gas will be conducted to feed the fire.

Hydrogen gas, though itself inflammable, extinguishes burning bodies, and is incapable of maintaining combustion. Bring an inverted jar filled with hydrogen gas over the flame of a candle, and depress the jar, so that the lighted wick may be wholly surrounded by the gas; the candle will be immediately extinguished.

Hydrogen gas is only inflammable when in contact with atmospheric air or oxygen gas. Fill a small phial with hydrogen gas, and take it from the pneumatic trough, placing the thumb on the mouth thereof, to prevent the gas from escaping; if a lighted taper be applied to the mouth of the phial, the gas will take fire, and burn with a lambent flame. The gas will only burn where it is in contact with the atmospheric air; the flame will descend gradually, till all the gas is consumed.

If the hydrogen gas be pure, the flame will be of a blue colour; but if the gas holds any substance in solution, which is generally the case, the flame is tinged of different colours, according to the substance. It is usually reddish, because the gas holds in solution a little charcoal.

On this principle is constructed the philosophical candle, which cannot be easily blown out. Fill with hydrogen gas a bell glass, furnished with a capillary tube; compress the gas, by making the bell descend below the surface of the water in the pneumatic trough; then apply a lighted taper to the upper extremity of the tube; the gas will take fire, and exhibit a candle, which will burn till all the gas is exhausted.

Artificial fire-works may be constructed by filling bladders with hydrogen gas, and connecting them with revolving jets, tubes, &c., bent in different directions, and formed into various figures pierced with holes of different sizes. The air which is forced through these holes by pressing the bladders, will, when inflamed, exhibit a curious firework, without either noise or smoke.

By the inflammable property of hydrogen gas, and the effects of electricity, a curious lamp has been invented by Volta, which, by turning a stop cock only, may instantly be lighted, and that many hundred times.

Hydrogen gas burns more readily in proportion as it is surrounded with a larger quantity of atmospheric air. Hydrogen gas and atmospheric air, or, what is better, oxygen gas, may be mixed together, so that every particle of each gas shall be contiguous to a particle of the other, in which case they will burn with great rapidity.

Into a strong bottle, capable of holding about four ounces of water, put one part of hydrogen gas and two of amospheric air. On applying a lighted taper, the mixture will explode with a loud report, and the inside of the bottle will become moist. It will be prudent to wrap a handkerchief round the bottle, to prevent it from doing any injury if it should burst.

The same experiment may be made with oxygen gas, instead of atmospheric air, changing the proportions, and mixing only one part of oxygen gas with two of hydrogen. The report will then be much louder than with common air.

This experiment may be made conveniently by means of an apparatus called the *inflammable air pistol.* To charge it, nothing more is necessary than to introduce its mouth inverted into a wide-mouthed bottle, filled with a mixture of oxygen and hydrogen gas, leaving it in for a few seconds; it is then to be stopped with a cork, and may be fired by the electrical spark taken from the prime conductor of the machine, or by a charged Leyden phial.

It has been, with great plausibility, conjectured, that the noise of thunder is the effect of the rapid combustion of hydrogen and oxygen gas, fired by the electric spark; and that the rain which falls so copiously at the time of thunder-storms, is owing to a sudden formation of water by this means.

From its lightness, it has been employed for making air-balloons, which have been already described.

Soap bubbles, filled with hydrogen gas, ascend in the air. To show this, fill a bladder with hydrogen gas, and fasten it to a tobacco-pipe; dip the bowl of the pipe into a lather of soap, squeeze the bladder gently, in order to form a bubble, and detach it in the usual manner. These bubbles will rise rapidly into the air: if a lighted taper be presented to them, they catch fire and burn with a slight explosion.

If the bladder be filled with a mixture of hydrogen and common air, the soap-bubbles will ascend, and when the taper is presented to them they will explode with a loud report. This experiment is more striking if oxygen gas be mixed with hydrogen. If the bladder be squeezed so as to form a great many bubbles on the surface of the bason, the report will be as loud as that of a cannon.

It has lately been discovered, that hydrogen, like oxygen, is an *acidifying* principle. United to chlorine, it forms *hydro-chloric acid*, which is the same as muriatic acid. Combined with iodine, it forms *hydriodic acid.*

When hydrogen gas is united to sulphur, it forms sulphureted hydrogen, which has also the properties of an acid. Tellureted hydrogen has also acid properties.

Hydrogen and Oxygen.

It has been already mentioned, that these two elements, when combined, form *water.*

Till lately, water was considered as a simple substance, or element; no one had ever been able to decompose it; and the decomposition of it, which is daily effected in natural processes, had escaped observation. We shall, however, give such evident proofs of the decomposition and recomposition of water, as will clearly show that it is not a simple body.

Experiment I.—A tube of common glass E F (Plate 2. fig. 7.), well annealed, and difficult to be fused, about ten or eleven lines diameter, was placed across a furnace C F E D, in a position somewhat inclined; and to its upper extremity was adapted a glass retort A, containing a known quantity of distilled water, and resting on a furnace V V. To the lower extremity of the glass tube F was applied a worm S S, connected with the double-tubulated flask H, and to the other tubulure was adapted a bent glass tube K K, destined to convey the gas to an apparatus proper for determining the quality and quantity of it. When the whole was thus arranged, a fire was kindled in the furnace C F E D, and maintained in such a manner, as to bring the glass tube E F to a red heat, but without fusing it; at the same time as much fire was maintained in the furnace V V X X, as to keep the water in the retort A in a continual state of ebullition,

In proportion as the water in the retort A assumed the state of vapour by ebullition, it filled the interior part of the tube E F, and expelled the atmospheric air which was evacuated by the worm S S, and the tube K K. The steam of the water was afterwards condensed by cooling in the worm S S, and fell drop by drop, in the state of water, into the tubulated flask H. When the whole of the water in the retort A was evaporated, and the liquor in the vessels had been suffered to drain off completely, there was found in the flask H a quantity of water, exactly equal to that which was in the retort A, and there had been no disengagement of any gas; so that this operation was merely a common distillation, which gave absolutely the same result as if the water had never been brought to a state of incandescence, in passing through the glass tube E F.

Experiment II.—Every thing being arranged as in the preceding experiment, twenty-eight grains of charcoal reduced to particles of a moderate size, and which had been previously exposed for a long time to a white heat in close vessels, were introduced into the glass tube E F. The operation was then conducted as before, and the water in the retort A kept in a continual state of ebullition, till it was totally evaporated.

The water in the retort A was distilled as in the preceding experiment, and being condensed in the worm S S, had fallen drop by drop into the flask H; but at the same time there had been disengaged a considerable quantity of gas, which escaped through the tube K K, and was collected in a proper apparatus. When the operation was finished, there was found nothing in the tube E F but a few ashes, and the twenty-eight grains of charcoal had totally disappeared.

The gases disengaged were found to weigh altogether 113.7 grains. There were found two different kinds of gas, viz. 114 cubic inches of carbonic acid gas, weighing 100 grains, and 380 cubic inches of a very light gas, weighing 13.7 grains. This last gas took fire, on being applied to a lighted body in contact with the air. In examining afterwards the weight of the water which had passed into the flask, it was found less than that in the retort A by 85.7 grains. In this experiment, therefore, 85.7 grains of water and 28 grains of charcoal formed carbonic acid gas equal to 100 grains, and a peculiar gas susceptible of inflammation, equal to 13.7 grains. To form 100 grains of carbonic acid gas, 72 grains of oxygen must be united to 28 grains of charcoal or carbon. The 28 grains of charcoal put into the glass-tube E F, took, therefore, from the water, 72 grains of oxygen, since there was formed carbonic acid equal to 100 grains. It appears, then, that 85.7 grains of water are composed of 72 grains of oxygen, and 13.7 grains of a substance forming the base of a gas susceptible of inflammation. The following is a proof of it.

The apparatus being arranged as above, instead of the 28 grains of charcoal, 274 grains of thin shavings of iron, rolled up in a spiral form, were introduced into the tube E F; the tube was then brought to a red heat as before; and, in the same manner, the whole of the water in the retort A was made to evaporate.

In this experiment there was disengaged only one kind of gas, which was inflammable; there was obtained of it about 406 cubic inches, weighing 15 grains.

The 274 grains of iron put into the tube E F were found to weigh 85 grains above what they did when introduced; and the water first employed was diminished 100 grains.

The volume of these iron shavings was found to be greatly enlarged. The iron was scarcely any longer susceptible of attraction by the magnet; it dissolved without effervescence in acids; in a word, it was in the state of a black oxyd, like that which has been burned in oxygen gas.

In this experiment there was a real oxydation of the iron by the water, entirely similar to that effected in the air by the aid of heat. 100 grains of water were decomposed; and of these 100 grains, 85 united to the iron, to reduce it to the state of black oxyd; these 85 grains, therefore, consisted of oxygen; the remaining 15 grains, combined with caloric, formed inflammable gas. It thence follows, that water is composed of oxygen and the base inflammable gas, in the proportion of 85 to 15, or of 17 to 3.

If it be true, as we have endeavoured to prove, that water is composed of hydrogen combined with oxygen, it thence results, that, by re-uniting these principles, water ought to be produced. This, indeed, is what takes place when, into a vessel filled with oxygen, a stream of hydrogen is introduced and set fire to.

In proportion as the combustion proceeds, water is deposited in the internal surface of the vessel; the quantity of this water gradually increases, and it unites itself into large drops, which run down the sides of the vessel, and are collected in the bottom of it.

In making this experiment, proper means were taken to ascertain the weight of the gases employed. Before the experiment, the vessel was weighed; and, by weighing it after the operation, the weight of the water that had been formed was obtained. Here, then, is a double proof; on the one hand, the weight of each of the gases employed; and, on the other, the weight of the water formed; and these two quantities were found to be equal within a two hundredth part. It was thus found that 85 parts by weight of oxygen, and 15 parts also by weight of hydrogen, are required to compose 100 parts of water.

These phenomena of the decomposition and recomposition of water are continually effected before our eyes, by the temperature of the atmosphere, and the agency of compound affinities. It is this decomposition which gives rise, at least in a certain degree, to the phenomena of spirituous fermentation, to those of putrefaction, and to those of vegetation.

Pure water is perfectly transparent, and has no taste nor smell. It is not liable to change. It can absorb a variety of gases; and when exposed to the atmosphere, it always contains a small quantity of common air, which may be separated by boiling, or by the air-pump. Rain-water is the purest which we see in nature; but, for delicate chemical processes, it is distilled in glass vessels. Spring-water generally holds some salts in solution, which gives it various properties.

Hydrogen gas combines with several simple bodies, constituting, with them, peculiar and distinct gases.

Hydrogen and Carbon.

Hydrogen gas unites to carbon, and forms, with it, *Hydro-carbonate gas.* Of this there are two kinds, according to the quantity of carbon which they contain.

Light Hydro-Carbonate. — This is frequently seen rising from stagnant ponds, when stirred. It may also be procured by passing the vapour of water over red hot charcoal. It burns with a pale blue flame. It is also called *Light carbureted Hydrogen.* It is contained very abundantly in many coal mines, where it is disengaged from fissures in the strata, often in great quantities; which are called by the miners *blowers.* When it has accumulated in any part of the mine, it forms an explosive compound, by its admixture with the common air: and when the miners approach it with lighted candles or lamps, it inflames with a tremendous explosion, killing the workmen and destroying the works. Indeed, nothing can be more terrible than such accidents; and there is reason to think that they have happened more frequently than is generally known. The body of miners are, therefore, infinitely indebted to Sir Humphry Davy for his invention of the *Safety-lamp,* an instrument which they can carry lighted into an explosive mixture, without any danger of setting fire to it. This gas is called the *Fire-damp* by the miners.

Bi-carbureted Hydrogen. — This gas contains twice as much carbon as the last. It is heavier than it, and is also called the *Heavy hydro-carbonate.* It burns with a bright white flame, like that of the best wax candles. It has been called the *olefiant gas*, because, when mixed with chlorine in an exhausted vessel, or over water, a peculiar fluid was formed, resembling a thick oil, but which has been termed by Dr. Thomson, *Chloric ether.*

Bi-carbureted hydrogen may be procured by heating, in a retort, four parts of sulphuric and of one alkohol; when the mixture boils the gas comes over.

Gas Illumination.—The carbureted hydrogen gases are now extensively employed for the purpose of giving light. When coal is put into an iron retort placed in a furnace, an inflammable gas is given out, which is a mixture of the two above-mentioned species of hydro-carbonate, together with small quantities of carbonic acid gas, carbonic oxide, sulphureted hydrogen, tar, ammonia, and water. These last substances are separated by passing the gas through a mixture of quicklime and water; and the purified gas then passes into the *gasometer*, from which it is distributed by means of pipes. The coal that has been thus acted upon, being deprived of its volatile principle, is converted into *coke.*

The kind of coal, fittest for the production of good gas, is that which contains most bitumen and least sulphur.

Messrs. J. and P. Taylor have lately taken out a patent for the production of carbureted hydrogen gas from *oil.* The oil is decomposed by suffering it to drop into a bent iron tube, laid through a furnace. The oil is separated into charcoal and bi-carbureted hydrogen, the flame of which much exceeds in whiteness and brilliancy that of coal gas, which is a mixture of the two species of hydro-carbonates. Another material advantage in the use of the oil gas is, that it is not mixed with the impurities of coal gas, many of which are highly injurious to health, and to the furniture of houses. From experiments it appears that the coal gas does not contain above 10 per cent. of bi-carbureted hydrogen; while the oil gas consists almost entirely of it.

Sulphureted Hydrogen Gas.

This is a combination of hydrogen gas with sulphur. It has an extremely fetid odour. It is inflammable. It cannot support life nor combustion: indeed, it is highly deleterious. Water can absorb it, and acquires its peculiar smell. The mineral waters of Harrowgate and Aix-la-Chapelle owe their properties chiefly to this gas.

Sulphureted hydrogen gas has the property of causing metallic oxides to re-approach the metallic state; the hydrogen of the gas attracting the oxygen. If a piece of paper, dipped in a solution of acetite of lead, be exposed to this gas, it instantly becomes blackened. If letters be written with the solution of lead, they will be invisible when dry, but will become black on exposing them to sulphureted hydrogen.

It has also acid properties. It unites with the alkalis and the earths, forming compounds called *Hydro-sulphurets*.

This gas affords an exception to the doctrine of Lavoisier, that oxygen was the only acidifying principle; for in it there is no oxygen, yet it performs the most important functions of an acid, reddening vegetable blues, and combining with alkalis. The hydro-sulphurets are formed by passing a stream of this gas through solutions of the alkalis.

Phosphorated Hydrogen Gas.

This gas consists of hydrogen and phosphorus. It is so combustible that it inflames by mere contact of atmospheric air. It has a very disagreeable smell, like that of putrid fish.

To procure it artificially, put one part of phosphorus and ten of a concentrated solution of potass, into a glass retort, and apply a gentle heat. When the mixture boils, the gas will come over, and may be collected in the pneumatic apparatus.

In preparing this gas, the body of the retort should be filled as nearly as possible with the mixture, otherwise the first portion of the gas, finding atmospheric air in the retort, inflames, a vacuum is produced, and the water is forced up into the retort, endangering the bursting of it.

If the bubbles of air which are formed in the retort are suffered to escape into the atmosphere, they will inflame instantly with a slight explosion; at the same time a beautiful dense white circular ring of smoke rises, and gradually enlarges as it ascends.

This gas may be made to burn under the surface of water. Put into a deep glass some phosphuret of lime, and half the quantity of oxy-muriate of potass: fill the vessel with water. Procure a long-necked glass funnel and plunge it into the vessel, putting it down to the bottom. Take some concentrated sulphuric acid and pour into the funnel. As soon as the decomposition of the water and that of the muriate takes place, flashes of fire will be seen to issue from the bottom of the vessel, having a green colour.

If a ribbon be impregnated by a solution of gold, and hung in a jar containing this gas, the gold will be revived, and will gild the ribbon.

CHLORINE.

This gaseous body is now generally regarded as an elementary substance: but it was lately considered as a combination of muriatic acid with oxygen, and was hence called *oxygenated muriatic acid gas.*

It is obtained by heating a mixture of muriatic acid and black oxide of manganese over a lamp: the chlorine will be evolved. In this process, according to the present theory respecting the elementary nature of chlorine, the oxide of manganese and muriatic acid decompose each other: the oxygen of the oxide unites to the hydrogen of the muriatic acid to form water, leaving the other constituent of the acid, viz. the chlorine, disengaged.

Chlorine is rapidly dissolved by water, the solution being of a pale yellow colour: it has a nauseous taste, and an extremely suffocating smell. When the gas is perfectly free from moisture, it has no action on vegetable colours, but, dissolved in water, it destroys them entirely.

From this property, it is extensively employed in shortening the process of bleaching linen, and also paper; but it is said that it is apt to injure the durability of the substances bleached, and no doubt, except due care is employed, this must be the case. Prints that have been stained by smoke and dust may also be whitened by it, as it does not act upon the printing ink.

Chlorine has likewise been found extremely efficacious in destroying the putrid effluviæ in prisons, and hospitals, and preventing the infection of the small-pox. But when used for this purpose, a small quantity only is diffused through the air, for, when taken into the lungs by itself, it is fatal to animal life; and, indeed, in preparing it, great precaution should be used not to inhale it, as it is extremely dangerous if not sufficiently diluted.

Notwithstanding its unfitness for respiration, it supports combustion in a remarkable degree. Some bodies, as phosphorus, and several of the metals, are spontaneously ignited when plunged into a vessel of chlorine; on this account it is now reckoned one of the supporters of combustion, a property which was lately supposed to be only enjoyed by oxygen. In this view, combustion is regarded only as the result of intense chemical action, and it is supposed that the compounds of chlorine have less capacity for caloric than their constituent principles, and, consequently, that caloric is evolved at the moment of their formation.

Chlorine is known to combine with oxygen in three different proportions, forming

1. *Oxide of Chlorine*, or *Euchlorine*, a gaseous body, not acid, having a smell less irritating than chlorine.

2. *Oxychloric Acid*, which does not exist independent of water or a base.

3. *Chloric Acid.* — Chloric acid cannot be obtained unmixed with water. It is colourless and

sour; acts on metals, and combines with alkalies, forming *chlorates*.

Chlorate of potash was formerly called oxymuriat of potash. It is a soluble white salt. When heated it gives out oxygen, and the residue is chloride of potassium. It forms extremely explosive compounds with phosphorus, sulphur, and charcoal. A grain, with a minute portion of phosphorus, laid upon an anvil, and struck with a hammer, makes a very loud report; but this experiment should not be attempted by the *young* student. From its detonating quality, it had been imagined that it could be used advantageously in the manufacture of gunpowder, but it has not succeeded.

Chlorate of potash is made by causing a stream of chlorine to go through a solution of caustic potash.

The combinations of chlorine with other simple bodies, form *chlorides*, if they are not acids, as chloride of sulphur, &c.

Chlorine and hydrogen. This compound body, which, according to the present nomenclature, is called *hydrochloric acid gas*, was known by the name of *muriatic acid gas*. It is readily obtained by distilling a mixture of common sea salt and sulphuric acid. The sulphuric acid combines with the soda, one of the constituents of salt; and the other constituent, the muriatic acid gas, is set free. Muriatic acid gas cannot support life nor combustion. It has a sharp pungent odour, and occasions white fumes when it is mixed with moist atmospheric air. It reddens vegetable blues. It combines with the alkaline bases: with ammoniacal gas it forms muriate of ammonia.

It is decomposed by the electric spark into hydrogen and chlorine.

It is readily absorbed by water, which then becomes very acid, and forms the liquid muriatic acid.

The *muriatic acid*, called also the *marine acid* and the *spirit of salt*, is in very common use. It is obtained, as above-mentioned, by distilling sea salt and sulphuric acid. It exists in a state of combination with alkalies and earths in the mineral kingdom in great quantity, chiefly with soda, lime, and magnesia. With soda it forms *muriate of soda*, common or sea salt, with which every part of the ocean is impregnated, and also some lakes. Muriate of soda also exists in the form of a rock in the earth, whence it is extracted: it is called *rock salt*. The most considerable mines of rock salt are in Poland; extensive mines are also worked in Hungary, Spain, and Cheshire in England. Muriate of soda is obtained also from the sea water, by driving off the water by evaporation; and this is done either by exposing salt water in shallow places, called *salt pans*, to be evaporated by the heat of the sun, or by boiling salt water in vessels, or by these methods combined. Muriate of soda, so procured, is always contaminated with muriate of magnesia and muriate of lime, from which the salt is purified by different processes.

IODINE.

This substance, considered as a simple body, has been but lately discovered. It exists in certain marine plants, and is procured from *kelp*, which is made by burning them. It is obtained first in the form of fumes, of a violet color, which condense in small opaque crystals of a blackish grey color and metallic lustre, resembling plumbago. It appears to be an element that exists in small quantity. It is capable of producing acids by combination with other substances. With oxygen, it forms *iodic acid;* and, with hydrogen, it forms *hydriodic acid.* It combines with phosphorus at the common temperature, giving out heat and light, and produces with it *phosphuret of iodine.* With sulphur, it makes *sulphuret of iodine.*

Iodine, also, unites with all the metals, forming with them *iodurets.*

SULPHUR.

Sulphur, known also by the name of *brimstone,* is a mineral substance, frequently found pure in nature.

It is of a pale yellow colour, without taste and, also without smell, except when heated. It is chiefly a volcanic product, and a great deal of what is used in this country is brought from Italy and Sicily. It is found also in nature combined with most of the metals as *ores:* united to iron, it forms *iron pyrites.*

Sulphur is extracted from pyrites by exposing it to heat in tubes, by which the sulphur is driven out and received in vessels with water: when melted and poured into moulds, it constitutes the *roll sulphur* in common use. A good deal of this is made in England. The sulphur thus obtained, however, is not quite pure. To purify it, it is sublimed by a gentle heat in close rooms, and thus forms *flowers of sulphur.*

If sulphur be exposed to heat it will soon fuse, and, by continuing the fusion for some time, it will become thick and tenacious. If worked between the fingers under water in this state, it acquires a consistency like wax, and may be employed for taking impressions from seals or gems. This change in the sulphur has been ascribed to *oxydation;* but the same effect takes place if the sulphur be kept in fusion without access of air.

Sulphur becomes electric by friction, and then exhibits negative electricity. It is soluble in oils. It does not combine with charcoal, but unites to phosphorus by means of heat. Sulphur and iron have a great attraction for each other. If a bar of iron be heated to whiteness, and then touched with a roll of sulphur, the two bodies combine and drop down together in a fluid state, forming sulphuret of iron. Sulphur also unites to potash and to soda, by melting them together in a crucible : by this liver-brown substances are formed, called *sulphurets* of *potash* or of *soda*, which are soluble in water.

Sulphur is a highly inflammable body, burning with a pale blue flame. Put some threads, dipped in sulphur, into a vessel floating in water. Set fire to them, and cover the whole with an inverted glass. The threads will continue to burn for some time, and the receiver will be filled with a dense white vapour. This vapour is the *sulphurous acid*, formed by the union of the sulphur and the oxygen during the combustion. It is absorbed by the water which will ascend in the receiver.

Let the whole then be left till the vessel is become again transparent. If the water be examined, it will have a suffocating odour and an acid taste.

Sulphurous acid, or the vapour of burning sulphur, has been found very useful for destroying the infection of clothes and small uninhabited places, and for fumigating letters from contagious places. It is used in dyeing, and for whitening straw and silk.

Sulphuric Acid.

This acid is composed of sulphur and oxygen, and contains a greater proportion of oxygen than sulphurous acid.

This acid is the same with that commonly known by the name of *Oil of Vitriol.* It was so called originally, because it was procured from *green vitriol;* now called sulphate of iron.

Common oil of vitriol has strong acid properties. It is of an oily consistence, and has usually a brown tinge, from impurities. It is inodorous, and about twice as heavy as water. It is highly corrosive, acting strongly on vegetable and animal substances.

It attracts water very strongly, and cannot be entirely separated from it by any known process. When exposed to the air, it attracts the watery vapour in the atmosphere, so as to increase rapidly in weight, which will be doubled in a month. If mixed with cold water, it suddenly becomes extremely hot, even more so than boiling water; and on this account, when it is necessary to dilute it with water, this should be performed very gradually.

Sulphuric acid is now made by burning sulphur mixed with nitre, in close chambers, entirely lined with lead, on the floor of which a thin layer of water is put. The combustion of the nitre furnishes oxygen to the sulphur, and the sulphuric acid is condensed in the water. It is in this manner that the common oil of vitriol is made: but it then contains many impurities; when freed from these, it is colourless.

If sulphuric acid be heated in contact with a combustible body, as charcoal or mercury, it loses part of its oxygen, and is then converted into *sulphureous acid gas*, which must be collected over mercury, as it is absorbable by water.

CARBON.

This elementary body is widely diffused throughout nature. *Common charcoal* consists of it, mixed with a small quantity of foreign matter. The purest variety of charcoal is *lamp black*.

Carbon exists as a constituent principle in all vegetable and animal matters, and remains fixed, after all the volatile parts have been carried off, during the process of combustion.

Charcoal is very nearly the same, from whatever it has been procured. It is always black and brittle, and exhibits the fibrous structure of the wood. It is not at all liable to change, and hence wood is sometimes charred on the outside, when driven into the ground for piles, and similar uses.

The diamond, a substance so very different in appearance, has been found by experiment to be only crystallized carbon. Diamonds are found only in Asia and Brazil, and always in the alluvial soil. Diamond is the hardest body, and can only be cut by its own powder. When found in the earth, they are crystallized, but are usually *rough*, having lost the angles of their crystals by attrition. They may be cleaved or split, and are then cut with facets for jewellery. They are of various colours. The diamond was long thought to be an incombustible body, but it is now known to be capable of being burnt; and by its union with oxygen, it forms carbonic acid. But although we know that diamond is only carbon, no attempts to crystallize carbon, and thus to make diamonds, have succeeded. Art cannot always imitate the processes of nature, even when the materials she has used are known.

Carbon and Oxygen.

Carbon unites to oxygen in two proportions. We shall first consider the most common one :

Carbonic Acid.—If charcoal be burnt, it combines with the oxygen of the atmosphere, and thus forms an acid, which, however, cannot be condensed into the liquid form, but is always *aërial.* Carbonic acid exists in great abundance in nature, combined with mineral bodies, chiefly lime. All limestones are formed of carbonic acid in a fixed state, united to lime. Hence this gas was at first called *fixed air*, which name is still sometimes used.

It may be procured from limestone or marble, in the following manner: put a quantity of broken pieces of marble or chalk into a retort, and add to it some sulphuric acid, diluted with six times its weight of water; a brisk effervescence will ensue, and the carbonic acid gas will be disengaged, and may be collected in the pneumatic apparatus. In this process the sulphuric acid severs the lime, leaving the carbonic acid free, which escapes in the gaseous form.

Carbonic acid gas cannot support flame, as may be seen by plunging a lighted taper into a vessel of it: it will be instantly extinguished.

It is fatal to animal life: a small animal confined in it would die in a few minutes.

Its taste is *sour:* and it is capable of being absorbed by water. Water so impregnated has an acidulous taste, and reddens vegetable blues. Many mineral waters owe their qualities to this gas, which is contained in them, and they may be imitated by impregnating water with carbonic acid gas. Agitation and pressure promotes the absorption; and in this manner the artificial soda water is made.

During the process of fermentation, this gas is disengaged, and *yeast* is carbonic acid enveloped in a viscous substance. If a lighted candle be plunged into the upper part of a cask containing fermenting liquor, it will be extinguished, the apparently empty part of the vessel being filled with carbonic acid gas.

This gas is heavier than common air; hence, when disengaged, it occupies the lowest situation. It may be poured from one vessel into another, which makes a pretty experiment. Fill a vessel with this gas, and then, having placed a bit of lighted paper in the bottom of an empty tumbler, pour the gas into the tumbler upon the taper: the flame will be extinguished: here the gas will be invisible, but its presence is thus manifested.

This gas is often found in the lower part of caverns, wells, mines, and other subterranean places. In mines it proves frequently fatal to the miners, who call it the *choke damp*. Wells, or similar places, which have been shut up for a long time, should never be entered without first putting down a lighted candle: if this is extinguished, it is not safe to go down. There are some caverns in which this gas is produced in so great a quantity, that it runs out at the opening, like a stream of water: this is particularly the case with the celebrated Grotto del Cane. A dog is suffocated if it be held for a short time in the lower part of the cavern, but the upper part is free from this gas.

Charcoal should never be burnt in rooms that have no chimney, because the red hot charcoal unites with the oxygen of the atmosphere, and forms carbonic acid, which cannot escape. Some melancholy accidents have happened from this cause. This gas has also been called *mephitic air*, from its suffocating quality.

Carbonic acid combines with all the alkalies, and with the alkaline earths, lime, magnesia, barytes, and strontia. With these it forms a class of salts, called *carbonates*.

Carbon does not combine with any of the metals except iron. This combination is the *carburet of iron*, called also *plumbago* and *black lead;* which, however, contains only five per cent. of iron. It is the substance used for making black lead pencils.

Carbonic Oxide.—This body is always gaseous. It contains only half as much oxygen as carbonic acid does. It is void of taste and smell, and fatal to animal life. It is inflammable, burning with a blue lambent flame, but does not explode when mixed with atmospheric air. It is procured by depriving carbonic acid of part of its oxygen. This is effected by exposing equal parts of chalk and filings of zinc to a gradual red heat, suffering the first product to escape, which is carbonic acid gas. The zinc deprives the carbonic acid in the chalk of part of its oxygen.

Carbon and Nitrogen.

This combination is called *cyanogen.* It is a gaseous body, having a penetrating and peculiar smell, and burning with a purple flame. It reddens vegetable blues.

When cyanogen combines with hydrogen, it forms a triple compound, called *hydrocyanic acid:* this is also called *Prussic acid.* Prussic acid is a liquid having a very pungent odour, like that of bitter almonds. It is extremely acrid, and highly poisonous. It is called Prussic acid, because it forms one of the constituents of the well-known pigment *Prussian blue*, which is a combination of hydrocyanate of iron with alumine.

PHOSPHORUS.

This highly inflammable substance is not met with in nature uncombined; but it exists combined with oxygen, forming phosphoric acid, in many animal and mineral substances.

Phosphorus is a yellowish semi-transparent matter of the consistence of wax. It is luminous in the dark at the common temperature of the atmosphere.

To show this property in a striking manner, write with a stick of it upon black or purple paper, or any other smooth surface; the writing will be luminous as if on fire. The fiery appearance disappears and appears again by blowing upon it. It is necessary, in making this experiment, to cut the phosphorus under water, and to put it into a quill, in order to defend the hands, lest it should take fire; and great care ought to be taken lest any particle should be left under the nails, or in any other place, for if this were afterwards to take fire it might occasion very serious accidents, as a burn by it is extremely severe.

Very slight friction is sufficient to inflame phosphorus. Put a grain of it into brown paper and rub it with some hard body, and it will take fire and inflame the paper. It takes fire spontaneously, and burns rapidly in the open air at 122° Fahr., with a brilliant flame. On this account, it is always kept under water; and it should never be suffered to lie exposed to the air.

Phosphorus is obtained by decomposing the phosphoric acid by means of charcoal in a retort. The oxygen of the acid unites to the carbon, forming carbonic acid; and the phosphorus distils over into water. The phosphoric acid is obtained by decomposing calcined bones by sulphuric acid. Bones consist chiefly of phosphate of lime; and in this process the sulphuric acid joins to the lime, leaving the phosphoric acid free.

Phosphorus is soluble in oil in small quantity, which is thus rendered luminous. Sulphuric and nitric ether, and ardent spirit, dissolve it, though sparingly, in the cold.

Phosphorus and Oxygen.

Phosphorus unites with oxygen in two proportions, forming *phosphorous acid*, which contains the lowest proportion of oxygen; and *phosphoric acid*, which contains the greatest proportion.

Phosphoric acid may be made by the rapid combustion of phosphorus in oxygen; but it is usually obtained from calcined bones, by decomposing them with sulphuric acid.

Phosphorus has the property of de-oxidizing several metallic solutions, as those of gold, silver, copper, mercury, lead, tin. If a stick of phosphorus be left in a concentrated solution of nitrate of copper, the copper will be precipitated upon the phosphorus in a metallic state.

It also combines with lime, forming *phosphuret of lime*. When pieces of phosphuret of lime are dropt into water, flashes of fire are seen to rise out of the water, which is occasioned by the phosphuret decomposing the water, and part of the phosphorus uniting to the hydrogen gas, forming phosphuretted hydrogen gas, described before.

The phosphurets of barytes and strontia have similar properties.

Phosphorus combines with chlorine and with iodine; and also with sulphur and the metals. Its union with hydrogen has been already noticed as phosphuretted hydrogen gas.

BORAX.

This elementary substance is known only in the boracic acid, which consists of it united to oxygen.

Boracic acid is rarely found native, but is generally procured from the salt called *borax.*

Borax is boracic acid united to soda, or a *borate of soda.* This is the *tincal* brought from Asia purified. It is found at the bottom of certain lakes in Thibet, and in China. The boracic acid has been decomposed but lately, when it yielded to the application of galvanic electricity by Sir H. Davy. Borax is in the form of a powder of an olive colour. It is combustible.

Borax is much used as a flux in soldering metals, and also for such stones as cannot be brought into fusion by alkalies.

FLUORINE.

This name has been given, provisionally, to the supposed base of the fluoric acid, which is imagined to consist of fluorine and hydrogen.

The *fluoric acid* has hitherto resisted all the endeavours that have been made to decompose it completely; and its real nature, therefore, continues uncertain. According to the present nomenclature, it is now sometimes called *hydro-fluoric acid.*

Fluoric acid is obtained by adding sulphuric acid to some pounded pure fluor spar, and applying heat.

Fluor spar is that mineral well known by the name of *Derbyshire spar,* because very abundant in that county. It is employed for making vases and other ornamental works. It consists of fluoric acid and lime, or, perhaps, calcium, the metal of lime, and is hence called also *fluat of lime.* The sulphuric acid, having a stronger attraction for lime than fluoric acid has, expels the latter and unites itself to the lime.

It appears, that before the researches of Gay Lusac and Thenard, the pure fluoric acid had never been procured; what had been considered as fluoric acid, being, in fact, a different acid, the *siliceo-fluoric* acid. In their experiments, the leaden receiver was cooled by ice, and the fluoric acid condensed into a liquid form. In this state it is the most caustic substance known, corroding the skin instantly, and causing dangerous sores.

Fluoric acid combines with silica, and becomes with it a permanent acid gas, called the *siliceo-fluoric acid*. This was formerly called *fluoric acid gas*. It has a pungent irritating odour, will not support combustion, and forms white vapours when it comes in contact with the air. It corrodes glass, and combines rapidly with water, forming the liquid siliceo-fluoric acid. This acid, formerly called the *fluoric*, also acts on glass, and is very acid and corrosive. In the process for making it from fluor spar and sulphuric acid, a little silicious matter generally existed in the spar, or glass vessels, that had been used; and thus the siliceo-fluoric, and not the fluoric acid, had been obtained.

Fluoric acid forms *fluates* with the alkalies and salifiable earths.

It also unites to borax, forming an acid called the *fluo-boric acid*. This does not act on glass, and is not so corrosive as fluoric acid. It gives rise to *fluo-borates*.

ALKALIES.

Alkalies are an important class of bodies. They have received this name because one of them, *soda,* was procured in great abundance from a plant called *kali,* by the Arabians.

Alkalies have peculiar properties. They change blue vegetable colours to green, and yellow to reddish brown. They unite to oil and fat, forming soap; thus rendering them miscible with water. They have an acrid and peculiar taste. They are caustic, or act powerfully upon animal substances. They combine with acids, forming with them a peculiar class of salts in which the properties of the acid and alkali disappear.

Until lately, only three alkalies were known, potash, soda, and ammonia. The two former were called the *fixed,* the latter the *volatile alkali.* Their number is now increased by the addition of lithia.

POTASH.

Potash had long been known by the name of the *vegetable alkali.*

It is procured from the ashes of burnt vegetables in the following manner. Dried vegetables are burned in heaps; the ashes are collected and lixiviated with water. Thus the potash in the ashes is dissolved, while the rest of the ashes is insoluble. The solution is poured off from the sediment, and evaporated: what remains is the *potash* of commerce, which is of a grayish colour, and contains some impurities: these are separated by being heated in a furnace. It is then white, and is called *pearlash.*

All *wood ashes* have in them more or less of this alkali, and hence they are applied to the same purposes as potash, or pearlash.

Potash and pearlash procured in this manner are combined with a certain proportion of carbonic acid, but not so much as to destroy completely its alkaline properties: hence it is a *sub-carbonate of potash.* To free the alkali from the carbonic acid, another process is necessary. Twice its weight of quicklime is added to the pearlash, and the whole mixed with water. The carbonic acid having a stronger affinity to the lime than to the alkali, quits the latter, and forms carbonate of lime, which, being insoluble, falls down, while the purer alkali is kept in solution by the water, and is afterwards separated by evaporation. Sometimes it is still farther purified, if necessary, by mixing the whole with alkohol, which dissolves the pure alkali alone. The alkoholic solution ascends to the top of the fluid, and is drawn off by decantation.

Potash, when thus prepared, is a solid white substance, and is called *caustic* potash, from its property of corroding the skin and flesh when it is applied to it: on this account it is frequently employed by surgeons.

Caustic potash, when prepared by alkohol, is united to a portion of water, and is therefore a *hydrate of potash.* It may be obtained free from water by another process.

Potash may be made to combine with a greater proportion of carbonic acid than in the state of sub-carbonate, by causing a stream of carbonic acid gas to pass through a solution of the latter salt: when this solution is then evaporated, it affords crystals of *bi-carbonate of potash.* This salt is milder than the subcarbonate, and its crystals are not deliquescent.

The fixed alkalies were, until lately, regarded as simple bodies, and one of the most brilliant discoveries of modern chemistry has been that which showed them to be the oxides of peculiar metals.

The decomposition of the alkalies was effected by means of voltaic electricity. By acting upon a very small piece of caustic potash, the metallic base was liberated, and proved to be solid, malleable, and having a high metallic lustre resembling mercury. This new metal is called *potassium*. It differs considerably in its properties from all the metals previously known. It is lighter than water, and has so strong an attraction for oxygen, that it almost instantly attracts it from the atmosphere and returns to the state of oxide. If thrown into water, it produces a very singular phenomenon; it decomposes the water so rapidly that an explosion takes place, accompanied by a flame. The same effect is seen if a globule of the metal is placed upon a piece of ice. This metal can only be preserved by keeping it under naphtha, a liquid that does not contain oxygen as one of its constituents.

Potash combines with all the acids forming neutral salts.

Nitrate of potash, called also *nitre*, or saltpetre, is produced in considerable quantities naturally, particularly in Egypt. It has also been produced artificially by making beds of animal and vegetable substances, mixed with calcareous and other earths. In process of time, an efflorescence of nitrate of potash appears, and is separated by lixiviation. By the decomposition of these substances, nitrogen is disengaged, which, uniting to the oxygen of the atmosphere, forms nitric acid; and this uniting to the alkali furnished by the vegetables and soil, produces the nitre. Nitrate of potash has the property of detonating when inflamed with charcoal or other easily inflammable bodies.

It is upon this property that *gunpowder* is formed, which consists of five parts of nitrate of potash, one of charcoal, and one of sulphur. *Chlorate of potash* is formed by passing chlorine gas through a solution of caustic potash. It is also called *oxy-muriate of potash.* This salt detonates violently when three parts of it mixed with one of sulphur are triturated in a mortar, or struck on an anvil. With phosphorus the effect is still greater. It makes a powerful gunpowder when employed as an ingredient.

If a small quantity of it be mixed with some sugar, and sulphuric acid be added, a sudden and vehement inflammation will be produced. These experiments require great caution.

SODA.

This has also been called the *fossil or mineral* alkali, because supposed peculiar to the mineral kingdom. It is obtained chiefly from the ashes of marine plants; all the fuci yield it in abundance; when burnt, their ashes are called *kelp,* which contains a considerable proportion of this alkali. *Barilla* is the same, procured by burning a plant of that name in Spain. Soda is also found in large quantities in different parts of the earth, particularly Egypt; and common sea-salt consists of it united to muriatic acid.

In all these cases, however, the soda is combined with carbonic acid. Of this there are two varieties, the *carbonate,* obtained by dissolving the soda of commerce and crystallizing it, and the *bi-*

carbonate, obtained by passing a stream of carbonic acid gas through a solution of the former.

Soda and potash considerably resemble each other, but the former does not deliquesce so as to liquefy, as potash does; its crystals, however, effloresce or fall to powder. It is used in the manufacture of soap and of glass.

Soda, also, like potash, consists of a metallic base united t oxygen. The metal is called *sodium*. It resembles potassium in most of its properties. It unites with chlorine, forming *chloride of potassium*; this is the common sea-salt so much used in food, and was, till lately, called *muriate of soda*.

Common salt exists in immense quantities in nature, both in the form of a rock, as *rock-salt*, which is dug out of the earth in a solid form, and also dissolved in the sea, from which it is obtained by evaporation.

Common salt is decomposed by sulphuric acid. The sodium is converted into soda, by taking oxygen from the water of the sulphuric acid, and the chlorine combines with the hydrogen of the water thus set free, and forms *hydro-chloric acid gas*, which is the same with what has been called *muriatic acid gas*. This gas, absorbed by water, forms muriatic acid. Hence, since muriatic acid was thus procured from sea-salt, it was supposed to exist in it, combined with soda, whence the name muriate of soda.

Soda unites with all the acids, forming neutral salts, the most remarkable of which are the following:—

Sulphate of soda, called formerly *Glauber's salts*, is formed abundantly in the process for procuring the muriatic acid from common salt; the sulphuric acid which is employed uniting to the soda.

Borate of soda, or borax, and

Phosphate of soda, useful as a test.

The fixed alkalies readily combine with oils, and thus form *soap*. Soap is soluble in water, and owes its detergent quality to the alkali contained in it. Alkali by itself would be too powerful, and would be apt to destroy the linen and other substances to be cleaned.

Soap when in solution is decomposed by acids, which unite with the alkali; hence if an acid is contained in water, the soap curdles. Neutral salts formed by acids with bases of the earths produce the same effect. *Hard waters* are such as have earthy salts, and are unfit for washing; *soft water* is that which is quite free from salts.

Hard soap is made from soda rendered caustic by lime, and olive-oil, or tallow. *Soft soap* is composed of potash and whale-oil.

LITHIA.

This alkali was lately discovered by M. Arfvredson, a Swedish chemist. It is found to be a constituent of certain stones, and has been met with in the petalite, spodumen, and lepidolite. It is of the class of fixed alkalies; is soluble in water, has an acrid taste, and changes vegetable blues to green. It forms neutral salts with the acids.

Lithia, like the other fixed alkalies, has been found by analysis to be the oxide of a peculiar metal, which has been called *Lithium*. Its decomposition has been effected by the voltaic pile, but the quantity of metal obtained has been extremely small.

AMMONIA.

This substance is known also by the name of the *volatile alkali.* It is composed of nitrogen and hydrogen. In its purest form it is in the gaseous state. It is then called *ammoniacal gas.*

Ammoniacal gas is procured by adding dry quicklime to muriate of ammonia, and exposing them in a retort to the heat of a lamp. The muriatic acid, having a stronger attraction for the lime than it has for the ammonia, leaves the latter, which is disengaged, in the state of gas. A pneumatic apparatus is necessary for this purpose, as this gas is rapidly absorbed by water. Ammoniacal gas has a strong pungent smell, and suffocates animals immersed in it. It changes vegetable blues to green. If water be introduced into the apparatus, in contact with the gas, it absorbs it entirely, and acquires its peculiar smell: this is a solution of ammonia in water, and is called *liquid ammonia.*

Ammonia exists as a constituent in animal bodies; and it is obtained from bones, horns, &c. It is a valuable material in manufactures and medicine. Ammonia forms with the acids several valuable compounds.

With carbonic acid it forms *carbonate* and *bicarbonate* of ammonia. The carbonate may be obtained by mixing ammoniacal gas with carbonic acid gas over mercury. The two gases immediately combine and form a solid white body, which still retains some of the pungent smell of the ammonia. This is the common *smelling salts.* The bi-carbonate is procured by causing a current of carbonic acid gas to pass through liquid ammonia. It has no smell.

Muriate of ammonia was called *sal ammoniac* from its having been originally brought from the neighbourhood of the Temple of Jupiter Ammon. It is now abundantly prepared in this country by saturating carbonate of ammonia with sulphuric acid, which forms sulphate of ammonia: by decomposing this salt by muriate of soda, muriate of ammonia and sulphate of soda are obtained. Sal ammoniac is employed in many processes.

EARTHS.

At the first view it would seem, from the vast variety of soils on the surface of the globe, and the number of rocks and stony substances, that the different earths of which they are composed were innumerable: nevertheless, their number is very limited, and, by the mixture of these, the greatest part of mineral bodies is composed.

The earths were formerly considered as elementary substances, but late discoveries have shown that most of them are, like the alkalies, metallic oxides. It is found, however, more convenient still to consider them as a separate class.

The earths are of two kinds:

1. Those which have some of the properties of alkalies and which are called *alkaline earths.*

2. Earths simply so called.

The alkaline earths are, lime, magnesia, barytes, and strontia. They unite with acids forming compound salts as alkalies do: like them they change vegetable blues to green; they have a considerable degree of causticity and taste, and are soluble in water.

The rest of the earths are insipid, and are scarcely at all soluble in water, and have no action on vegetable colours.

LIME.

Lime is one of the most abundant substances in nature. It is the chief constituent in vast mountains and rocks, and is very generally distributed, mixed with other earths. Chalk, marble, calcareous spar, and all those rocks called lime-stones, consist of it.

In these substances, however, the lime is not pure or uncombined. It exists in them united to carbonic acid, constituting *carbonate of lime.*

To obtain pure lime, these stones are exposed to a white heat, by which the carbonic acid is driven off in the gaseous state. This is called the *burning of lime.* The stone so treated is then called *quicklime;* or, in chemical language, properly *lime.*

Quicklime, or pure lime, is white; has a hot acrid taste, and is caustic, or corrodes the skin. It changes vegetable blues to green.

Until the discovery of the bases of the alkalies by Sir Humphry Davy, lime, as well as all the other earths, was considered as an elementary substance; but it has been ascertained to be the oxide of a metal to which the name of *calcium* has been given. From the extreme difficulty, however, in reducing lime to this state, the properties of calcium are but little known. It is white and solid, resembling silver, and soon returns to the state of oxide or lime by attracting oxygen from the air.

When water is thrown on quicklime just burnt, it swells, bursts, and falls to powder; giving out, at the same time, much steam and heat. This is called the *slaking of lime.* In this process, the water unites to the lime, and becomes solid; for slaked lime is quite dry. It is, therefore, called a *hydrate of lime.*

Lime is soluble in water: the solution has an acrid taste, and is called *lime-water.* When lime-water is exposed to the air, a stony film forms upon the surface, owing to the lime attracting carbonic acid, and returning to the state of carbonate, which is insoluble in water. This film breaks, falls down, and is succeeded by others in succession. Fresh quicklime has a strong tendency to attract moisture from the air, and also carbonic acid, so that it must be kept in closely-stopped vessels.

Quicklime is used for making mortar for building, by mixing it with sand. This, by solidifying the water and attracting carbonic acid, becomes a very hard substance like stone. The lime should be newly burnt, and the sand silicious and free from impurities. It is also extremely valuable as a manure when put upon the land.

Carbonate of lime is not caustic, nor soluble in water. It is decomposed by the stronger acids. Put chalk or marble into a vessel, and pour upon it diluted sulphuric or muriatic acid; an effervescence will ensue, which is owing to the escape of the carbonic acid. Hence these acids are employed to distinguish lime-stones.

Lime combines with phosphorus, forming *phosphuret of lime*, to be afterwards described. With sulphur it forms *sulphuret of lime.*

It also combines with all the acids, forming a great number of neutral salts.

Sulphate of lime, called also *gypsum*, exists largely in a natural state. When burnt, it forms the substance called *plaster of Paris*, so much employed in making casts of statues, and in plastering rooms.

Fluate of lime, or lime united to the fluoric acid, is the substance so well known by the name of Derbyshire spar, and which is much used for vases and other ornaments.

Nitrate of lime is a very soluble salt; its taste is acrid and bitter. It is often found efflorescing on old plaster walls.

MAGNESIA.

This earth, when pure, is white, nearly destitute of taste and has no smell. It is insoluble in water, but changes vegetable blues to green, and unites to the acids. It is conjectured to be composed of a metallic base, *magnesium*, united to oxygen; but the metal has not yet been distinctly obtained.

Native magnesia is a rare substance, but it enters as a constituent in many rocks, as serpentine, steatite, &c.

Carbonate of magnesia is extensively employed as a medicine. When a red heat is applied to it it loses its carbonic acid, and becomes *calcined magnesia.*

Sulphate of magnesia is known by the name of *Epsom salt*, because formerly procured from the springs of Epsom, in Surrey.

BARYTES.

This earth was formerly called *terra ponderosa*, from its great specific gravity. It has strong alkaline properties, a caustic taste, and changes vegetable blues to green.

It slakes in the air like lime, is soluble in water, and also in alkohol, the flame of which it causes to assume a yellow colour. It is a deadly poison. It is also found to consist of oxygen and a metallic base called *barium*.

Carbonate of barytes is found as a mineral, but it is not abundant.

Sulphate of barytes is found native more frequently. When calcined, it forms the *Bolognian phosphorus*.

Barytes is used as a white paint under the name of *permanent white*, not being liable to change its colour.

STRONTIA.

The name of this earth is derived from Strontian, in Argyllshire, in Scotland, where it was first discovered by Dr. Hope.

It is soluble in water, and changes vegetable blues to green.

It is also considered to be the oxide of a metal called *strontium*.

Strontia is not very abundant, and is always in nature found combined with the carbonic or sulphuric acids.

The other salts of strontia are but little known. All the salts of Strontia have the property of tingeing the flame of alkohol red.

SILICA.

This earth, which forms a large portion of the surface of the earth, exists nearly pure in flint and rock-crystal: hence it has been called the earth of flints.

It may be obtained pure as follows: calcine gun-flints till they become brittle, then pulverize them. Mix this powder with three or four times its weight of carbonate of potash, and fuse the mixture in a crucible, by a strong red heat. We shall thus obtain a compound of alkali and siliceous earth: dissolve it in water, and add to it diluted muriatic or sulphuric acid; a precipitation will take place, which, when well washed, is pure silex.

Siliceous earth, when pure, is white and tasteless. It is infusible by itself, and insoluble in water. It has a harsh feel, and does not form a cohesive mass with water.

No acid can act upon it, except the hydrofluoric, which dissolves it. When mixed with an equal weight of carbonate of potash, and fused in a strong furnace, it forms *glass.* With a larger proportion of alkali it forms a substance soluble in water, which has been called *silicated alkali.* The solution of this was called *liquor of flints.* The silex is precipitated from it in the state of a gelatinous hydrate by acids.

It is supposed that silica consists of oxygen united to a certain base, which has been assumed to be a metallic substance, and which has been called *Silicium:* but its real nature has not been ascertained. It is imagined, however, that silicium forms an alloy with iron, and that the properties of some sorts of iron are owing to the addition of this substance.

ALUMINA.

This earth forms a part of all clays, and hence has been called *argillaceous earth.* It exists also in numerous rocks, particularly slate, and even constitutes some of the hardest gems and stones, as the sapphire, ruby, and corundum.

It rarely occurs in a pure unmixed state. But it has been found native, in small masses, at Newhaven, in Sussex, and also in Hall, in Saxony.

Clay consists of this earth, joined to silex. *Porcelain clay* proceeds from the decomposition of felspar; it consists of silica, alumina, and sometimes a little lime and potash. *Pipe-clay*, and *potters'-clay* are pure clays, but of variable composition.

Alumina has no smell nor taste; is insoluble in water, but forms with it a ductile paste, and shrinks much when exposed to heat. It is dissolved by the liquid fixed alkalies, and unites chemically with barytes, strontia, lime, and magnesia. It is dissolved by most of the acids.

The salt called *alum*, which gives its name to this earth, is a sulphate of alumina and potash. Sulphate of alumina alone will not crystallize; but when sulphate of potash is added, octahedral crystals of alum are produced. When alum is exposed to heat, it loses part of the acid and water of crystallization, becomes light and spongy, and is called *burnt alum*. Alum is extensively employed in the arts of dyeing and calico printing, in consequence of the attraction which alumina has for colouring matter. Alumina also forms the basis upon which are precipitated certain colours used as pigments.

YTTRIA.

This rare earth, so called from Ytterby, in Sweden, where it was discovered, is found only in a stone called gadolinite, so named from Professor Gadolin. It is insipid, and insoluble in water, but dissolves in carbonate of ammonia. It forms salts which have a sweetish taste. Its specific gravity is greater than that of any other earth. The base of yttria has been supposed to be a metallic substance, which would receive the name of *yttrium;* but it has never been exhibited in a separate state. Yttria contains oxygen, and hence been inferred to be a metallic oxide.

GLUCINA.

Glucina, or *Glucine*, is an earth which has been procured only from the beryl, the emerald, and the euclase.

It derives its name from its forming salts which have a sweetish taste. It has no taste nor smell, is infusible by heat, but dissolves in the acids, and pure alkalies. It is insoluble in water. It is also supposed to be a metallic oxide.

ZIRCONIA.

Zirconia is a very rare earth, found as yet only in the *zircon* or *jargon* of Ceylon, and the *hyacinth*. It is void of taste or smell; is insoluble in water and pure alkalies; but is soluble in alkaline carbonates. Its base is supposed to be metallic.

THORINA.

This is another very rare earth, discovered by Berzelius, who extracted it from a species of gadolinite. It absorbs carbonic acid, and dissolves readily in acids. It is not soluble by the pure alkalies, but slightly so by the alkaline carbonates. It is supposed to be the oxide of a metal,

METALS.

We come now to treat of the last division of the metallic substances; those which, remaining in the air in the metallic state, have received the name particularly of *metals.*

Those metals whose combinations with oxygen form alkalies, as potassium, sodium, and lithium, as also those whose oxides form earths, as calcium, magnesium, barium, strontium, silicium, alumium, yttrium, glucinum, zirconium, and thorinum, have been already mentioned incidentally, in speaking of the alkalies and earths to which they give rise. But we shall now enumerate the general properties of this important class of bodies, including the above mentioned.

The metals are distinguished from all other substances by certain properties, particularly a peculiar lustre; and most of them have great weight, or specific gravity.

Several of them have been known to part of the world in very ancient times, while some savages in the present day are totally unacquainted with their use: but a considerable number of the metallic substances have been discovered only lately. The metals are so important in many mechanic arts, that mankind could never have attained their present state of civilisation without them.

Metals are, in general, solid bodies at the usual temperature: one only, mercury, is fluid.

They are opaque in the mass in its usual state; but gold, when beat into very thin leaves, transmits a faint greenish light, when held between the eye and the direct rays of the sun.

The lustre by which they are distinguished, called the *metallic lustre*, is not easily described, but may be exemplified in that of silver, steel, lead, tin, &c., as distinguished from that of glass, diamond, &c. Mica has a lustre which approaches that called the metallic, but it loses this on being scratched, while the metals do not; on the contrary, they are more brilliant when fresh cut. This property of the metals renders them highly useful for ornamental purposes, and for reflecting light, as in mirrors.

Metals are the best conductors of heat, and also of electricity.

Some of the metals are capable of being extended under the blows of a hammer, which property is called *malleability*, and is peculiar to metals. Others, again, are brittle, on which account they were formerly called *semi-metals*. The malleable metals are, gold, platina, silver, palladium, potassium, sodium, mercury in its frozen state, copper, iron, lead, tin, zinc, and nickel. These differ much in their degrees of malleability. Gold may be beat into the thinnest leaves, and zinc is very little malleable, except when heated. The malleable metals are also *ductile*, or may be drawn out into wire. Gold and platina may be drawn into the finest wire.

One of the metals, iron, is capable of being made very *elastic*, which renders it fit for making *springs*.

Most of the metals are very *fusible*, or capable of being rendered fluid by the application of heat; on this account they may be cast into moulds, and formed into various utensils: some of the metals are volatile at a high degree of heat.

None of them are very hard naturally; but some of them may be hardened by art: thus the moderns make cutting instruments of iron and steel, and the ancients made them of a combination of copper and tin.

All the metals are capable of combining with oxygen, and thus forming oxides; but they differ very much in the readiness with which they combine with it, which occasions their division into several classes.

The oxides of metals have none of the metallic brilliancy, and no malleability: their appearance and nature are totally different from that of the metals themselves.

The oxides of some metals, as potassium and sodium, are *alcaline;* others are acid, constituting the *metallic acids:* the rest have neither acid nor alcaline properties, but are, as well as others, capable of being dissolved by the acids, thus forming salts.

Some of the metals attract oxygen so strongly, that they become oxidized almost immediately in the open air, and even take oxygen from all its combinations, so that they are, with great difficulty, preserved in the metallic state; of this nature are metals that produce the alkalies and earths, which can only be kept in pure bitumen called naphtha, which has no oxygen in its composition.

Some of the metals do not experience any change on being kept in fusion by a strong heat with an access of air; but others are by this means converted into oxides. The first have been called *perfect metals*, and comprehend gold, platina, silver, and palladium. The rest differ very much in the degree of heat necessary to oxidize them. Arsenic, manganese, and the bases of the earths and alkalies become oxides at the usual temperature of the atmosphere, even when perfectly dry. Lead and copper are oxidized slowly by moist air. Iron, zinc, copper, tin, &c., require to be heated to redness. Although the perfect metals cannot be oxidized by any degree of ordinary heat, they may by the effect of electricity and galvanism. All the metals, that are converted into oxides by atmospheric air, undergo this change still more rapidly in oxygen gas, as was shown in the burning of iron wire in oxygen.

Metals are also converted into oxides by the action of acids, but in different manners. Some acids which contain oxygen loosely combined part with it to the metal; while others, as the sulphuric and muriatic acids, do not act upon iron or zinc, except they are diluted with water, and then it is the water, and not the acid, which supplies the oxygen.

Metals cannot be made to combine with all proportions of oxygen, but are susceptible only of certain degrees or stages of oxidation. Thus iron has only two oxides; the *black oxide* composed of 29.5 parts of oxygen, and 100 parts metal; and the *red oxide* of 43.5 parts of oxygen, and 100 parts of metal: and there are no intermediate degrees of oxidation, nor will iron combine with a larger or smaller proportion of oxygen. Metals differ in the number of oxides which they form: thus some have two, some three, and others four oxides: and, according to the law of the atomic theory, the different oxides of the same metal contain oxygen in proportions that are simple multiples of each other.

The different oxides of the same metals have different colours, which render them very valuable as pigments. They have also distinct chemical properties, and combine, in different proportions, with the acids, forming distinct salts.

All the metals are considered as simple bodies, none having been decomposed or resolved into other principles; also, at one time, they were supposed to be formed of a peculiar basis and an imaginary inflammable principle called *phlogiston*. This theory was very favourable to the idea of forming metals, and transmuting or changing them into each other. The existence of phlogiston is no longer believed in, and the science of alchemy is only remembered as affording an instance of the dangers of false theories, and of the great credulity of persons in many respects well informed.

The oxide of a metal was formerly called a *calx*, and its conversion was supposed to be owing to the loss of the phlogiston; but it was observed that the metal *gained* instead of *losing* weight by this change; in fact, it acquires just the weight of the oxygen it combines with. When the oxides of metals are made to part with their oxygen, hey are reduced to the metallic state, and upon this depends the art of reducing metals from their *ores*.

PLATINA.

This metal was unknown in Europe before 1748, and is still chiefly found in South America: it has been also found in Estremedura, in Old Spain.

In colour it is nearly as white as silver. It is very difficult of fusion, and can only be melted by the assistance of oxygen gas or by galvanic electricity. From its refractory quality, it is employed for crucibles and other chemical utensils exposed to heat, for which it is admirably adapted.

It is also extremely ductile and malleable, and may be drawn into very thin wire, and hammered into thin plates.

Platina does not tarnish on exposure to the atmosphere, and takes an excellent polish, on which account it is used in making specula for telescopes. It is also capable of being welded, a property only possessed by it and iron. It is the heaviest of the metals; its specific gravity being nearly 22.

Platina is readily dissolved by the nitro-muriatic acid and by chlorine, but is not acted upon by any other acid. It also combines with sulphur and phosphorus.

Platina is brought to Europe in small flattened grains, which, however, are not pure platina, but contain a mixture also of nine other metals. Four metals, *osmium*, *iridium*, *rhodium*, and *palladium*, were unknown till they were discovered in these grains.

GOLD.

Gold is found in nature in a metallic state. It is generally met with in grains called *gold-dust*, mixed with the sands of rivers, either being carried away by them from the rocks which contain it, or having been deposited in ancient alluvium. It is chiefly found in Africa, also in Brazil and Peru. There are mines of it also in Hungary; and it is met with in quantities too small to be worth working, in the sands of many rivers of Europe.

Lately some was found in the county of Wicklow, in Ireland; one grain weighed 22 ounces, and considerable expectations were formed; but, notwithstanding, the works were abandoned as unproductive.

Gold is the heaviest of the metals except platina. It is of a rich yellow colour, and not very hard when pure.

It melts at a bright red heat, but cannot be oxidated by any furnace, though it may by electricity and galvanism. It does not oxidate in the air; hence it is so useful in gilding, its beautiful lustre remaining untarnished.

It is the most ductile and malleable of the metals, and may be drawn into the finest wire for gold-lace and other purposes, and may also be hammered into leaves of extreme thinness for gilding.

Gold is not acted on by any acid except the nitro-muriatic acid and chlorine. From this property the former was named *aqua-regia*, gold being called by the alchemists the king of the metals.

The solution of gold, called muriate of gold, yields by evaporation crystals of a beautiful yellow colour, which, when dissolved in water and precipitated by a solution of tin, afford the beautiful powder called the *purple precipitate of cassius*, much used in enamelling. This consists of oxide of gold mixed with oxide of tin.

If any substance, as a piece of ribband, be dipped into the muriate of gold, and then exposed to a stream of hydrogen gas, the gold will be revived, and the substance covered with it. Some combustible bodies attract the oxygen from the solution of gold, and cause it re-appear in its metallic state. Thus, if a piece of charcoal be put into a glass-jar, containing a diluted solution of gold, and exposed to the direct rays of the sun, it will soon appear gilt. When ammonia is added to a solution of gold, a yellow precipitate is formed, called *fulminating gold*, because it has the property of exploding when exposed to heat.

If to a solution of muriate of gold, sulphuric ether be added, the gold will combine with the ether, leaving the acid, and will float on the surface of the fluid. If polished steel be dipped into this, it will be covered with a coating of metallic gold. This process is employed for gilding lancets, and other surgical instruments, to defend them from rust.

Gold easily alloys with mercury, which is, therefore, much employed for extracting it from the substances with which it is mixed in its natural state. The mercury, being volatile, is driven off by heat, and the gold remains free.

Gold in its purest state is too soft to be used as coin; it is, therefore, alloyed with $\frac{1}{12}$ of copper. Jeweller's gold generally contains considerably more.

Gold seems to have been one of the earliest known of the metals. The ancients were lavish in its use, and it is still frequently used in ornaments among savage tribes.

SILVER.

Silver is often found native, or in the metallic state, but it is most usually combined with other metals, or sulphur. In its native state it frequently assumes an arborescent form. The richest silver mines are in Mexico and Peru; but others exist in many countries. Lead ore very frequently contains a quantity of silver, and sometimes it is worth extracting.

Silver is of a brilliant white colour. It is very ductile and malleable; may be drawn into fine wire, and beaten into thin leaves; but it is inferior to gold in these qualities.

Silver fuses when heated red hot, and may be cast into moulds, but is not thus converted into oxide by any continuance of heat: it is oxidized by common and galvanic electricity.

It is not oxidized by the air; but it is tarnished by exposure, because the sulphurous vapours form with the metal a sulphuret of silver.

Oxide of silver is of a dark olive colour, and is obtained by precipitating it from the nitrate of silver by lime-water, this metal being soluble in the nitric acid.

Nitric acid can dissolve more than half its weight of silver, the solution depositing crystals. When these are fused by a gentle heat, they may be poured into moulds, and form the substance called *lunar caustic*, used in surgery.

Nitrate of silver is used by chemists as a test for muriatic acid; for if it be dropped into any liquid containing muriatic acid, a white precipitate will appear, owing to the superior affinity of silver to muriatic acid, and to the insolubility of muriate of silver. Nitrate of silver is very caustic, staining animal and vegetable substances of a black colour, and hence it is employed as a *permanent marking ink* for linen, and also for staining hair; though for this last purpose it should be used with great caution, and much diluted.

If a few drops of the nitrate of silver be put upon a piece of glass, and a copper wire be placed in it, a beautiful metallic precipitation of the silver will appear in an arborescent form.

When silver is precipitated from its solution in nitric acid by ammonia, it forms *fulminating silver*, which is a dangerous preparation; for it explodes by the slight contact of a body.

When mercury is added to the nitric solution of silver, a precipitation of metallic silver is formed resembling in appearance a vegetation, and called *arbor Dianæ*.

Silver is not soluble in the hydro-chloric acid (muriatic acid), yet, when this acid is added to a solution of nitrate of silver, it unites to the oxide, and a white curdy precipitate falls down, which is the *muriate of silver*, or, in conformity with the new nomenclature, the *chloride of silver*. If this precipitate be fused by a gentle heat, a semi-transparent mass is formed, called formerly *luna cornea*, or *horn silver*, the *fused muriate of silver*.

Silver is also dissolved by the sulphuric acid, and the *sulphate of silver* is used as a chemical test. Silver also unites to sulphur and phosphorus.

Silver, when employed for coin is alloyed with copper to increase its hardness. Our coin contains thirty-seven parts silver and three parts copper.

MERCURY.

This metal, called also *quicksilver*, is always fluid when in the usual temperature of the atmosphere; but when exposed to an intense degree of cold, it is frozen into a solid mass, and is then malleable. The temperature necessary for this purpose is 39°. The cold is sometimes so great within the polar circle as to freeze the mercury in the thermometer; but in this country that can only be effected by exposing it to a freezing mixture.

Mercury also boils at 655°, and then evaporates, and may be distilled from one vessel to another.

It is sometimes found in nature in a pure state, but usually it is united to sulphur, with which it forms the ore called *cinnabar*. The greatest quantity of it is found in Spain and South America.

When acted on by heat and air for a long time, it absorbs oxygen, and is converted into a red oxide called formerly *precipitate per se*: and when the heat is increased, the oxygen is given out, and the mercury re-assumes its metallic appearance. When it is agitated long in air, it is converted into the *black oxide*, which contains a smaller proportion of oxygen than the red oxide. It is the black oxide which is employed in mercurial ointment. Mercury is acted on by the acids, forming salts of mercury. It also unites to chlorine (oxymuriatic acid,) in two proportions, forming *calomel* and *corrosive sublimate*.

Mercury when triturated with sulphur, combines readily into a black compound called *ethiops mineral;* when united to a larger proportion of sulphur, it forms the beautiful pigment called *cinnabar*.

Mercury combines with several of the metals, forming soft alloys called *amalgams*. The amalgam with tin is used for mirrors: that with zinc is employed in electrical machines.

IRON.

No metal is so universally diffused throughout nature as iron. It is never found in the earth in the metallic state, but is always procured from ores.

Iron is of a bluish-grey colour. It is very ductile, for it may be drawn into wire as fine as human hair. It is also very malleable, and possesses the property of being *welded;* that is, of having two separate pieces united together by hammering when red hot. It is one of the most infusible of the metals, but may by intense heat be melted and run into moulds. It is in its pure state among the hardest of the metals, but may be made to exceed all the rest in hardness when converted into *steel.*

It possesses the magnetic property, the *load-stone* itself being an ore of iron.

Exposed to the action of the air and moisture, iron soon *rusts* or *oxidates.* It then attracts the oxygen and carbonic acid, and is changed into a reddish brown substance, which is a mixture of oxide of iron and carbonate of iron.

Iron unites to oxygen in two proportions. The *protoxide* of iron consists of one hundred parts of iron, and twenty-nine parts oxygen; it is of a black colour; hence it is called the *black oxide of iron,* formerly *martial ethiops.* It is formed when iron is heated red hot; scales form on the outside, which fly off when hammered. It is magnetic.

The *peroxide* is red, and consists of one hundred parts iron, and forty-three oxygen; it is called the *red oxide of iron.* The red oxide is formed by keeping iron filings red hot in an open vessel, and agitating them constantly till they are converted into a dark red powder, formerly called *saffron of Mars.*

Iron is acted on by all the acids, and various salts of iron are formed: the most remarkable are the following:—

Sulphate of iron, formerly called *copperas* or *green vitriol.*

Nitrate of iron, and *acetite of iron,* used in dying.

Ferro-prussiate of iron, called *prussian blue*, used as a pigment.

Iron also combines with sulphur, phosphorus, carbon, chlorine, and iodine.

Sulphuret of iron, composed of sulphur and iron, is called also *pyrites*. Iron with carbon forms *plumbago*, commonly called *black-lead*, used for making pencils. *Steel* is another compound of iron with carbon.

The ores of iron consist either of the black oxide, which is called the *magnetic iron ore*, the red oxide or the *red iron ore, carbonate of iron*, and *clay iron-stone*.

The iron is separated from these ores by smelting in furnaces, where it is made to flow out into various moulds made in a kind of loam. The first product is called *cast iron*. It contains some carbon and oxygen; and, it is thought, also silicium, besides casual impurities. Of this, cannon, pipes, grates, and other articles of cast iron are made. It is of two kinds: *white cast-iron* is very brittle; *grey cast iron* is less brittle, though not malleable, but may be bored and turned in the lathe.

To render iron *malleable* it must be freed from those substances with which it is combined in the crude state. To effect this, it is kept in fusion in a furnace exposed to air and flame, and well stired. The oxygen combines with the carbon, and escapes in the form of carbonic acid gas; and the earthy matter is vitrified, and rises to the surface as *slag*. It is then subjected to the action of large hammers and rollers, by which the remainder of the impurities is forced out. It then constitutes *bar iron*, also called *wrought iron*, fit for manufacturing.

Wrought iron is of a fibrous structure, and is the metal in a pure state. It is now extremely malleable, soft, and easily filed, and also capable of being forged and welded. There are several varieties of iron in this state, arising from the ores from which they were procured, the process of smelting, or the intermixture of foreign substances.

One variety is called *hot short iron;* it is extremely ductile when cold, and on this account is employed for making wire; but when heated it is extremely brittle: it is also fusible. *Cold short iron,* on the contrary, is highly ductile when hot, but brittle when cold. The causes of these qualities are not precisely known, but it is said that the first is iron combined with arsenic, and that the latter contains phosphoric acid.

Iron is capable of being reduced to a third state, which is that of *steel.* It is converted into steel, by exposing it to heat in contact with carbonaceous substances, which unite themselves with it. Steel is, therefore, iron united to carbon, and is made by three processes.

Natural steel is made by keeping cast iron in a state of fusion in a furnace, its surface being all the while covered deep with scoriæ; part of the carbonic acid gas escapes, while another part combines with the iron. This steel is inferior to the other kinds.

Steel of cementation is made by placing bars of iron in charcoal powder, and exposing them to a strong heat in a furnace for six or eight days. The iron and the carbon thus combined constitute what is here called *blistered steel.* When this is rendered more malleable by the operation of the hammer, it is called *sheer steel.*

Cast steel is made by fusing blistered steel with pounded glass and charcoal powder, in a close crucible. It is also made merely by fusing iron with carbonate of lime. This is the most useful of all the kinds of steel, and employed for razors, surgeons' instruments, and similar purposes; its grain is the most compact, and it takes the highest polish.

It is the particular property of steel to become extremely hard, if it be heated red hot, and then suddenly plunged into cold water; but different instruments made of steel require to be of different degrees of hardness; and they are, therefore, subjected to a process called *tempering*, which is heating them again to a certain point after having been hardened. The tempering of steel, for some purposes, is a delicate process.

A polished bit of steel, when heated with access of air, acquires very beautiful colours. It first becomes of a pale yellow, then of a deeper yellow, next reddish, then deep blue, and at last bright blue. At this period it becomes red hot, and the colours disappear: at the same time the metallic scales, or the black imperfect oxide of iron which is formed, incrusts its surface. All these different shades of colour indicate the different tempers the steel has acquired by the increase of heat. Artists have availed themselves of this property, to give to surgical and other instruments those degrees of temper which their various uses require. Iron may be alloyed with most of the metals, but these alloys are not much used.

Wootz is the name given to a kind of steel made in the East Indies, which is of a very superior quality for cutting-instruments.

COPPER.

Copper is sometimes found native, but in very small quantities. It is generally met with in the state of oxide, or united to sulphur, or to acids. In Cornwall there are very rich mines of copper.

Pure copper is of a red colour, very tenacious, ductile, and malleable. It melts at 27 of Wedgewood's pyrometer, and burns with a green flame.

It is not oxided by water. When exposed to a red heat, it becomes covered with a crust of oxide of a blackish colour, this is the *peroxide* of copper. The first, or *protoxide*, is of a red colour when found native,but when formed artificially is orange.

The oxides of copper are reduced to the metallic state by heating with charcoal or oils.

The nitric acid disolves copper with effervescence, and the solution has a blue colour. The acid first oxidates the metal, a large quantity of nitric oxide (nitrous gas), is disengaged, and the oxide dissolves; this forms the *nitrate of copper*.

The sulphuric acid does not dissolve copper unless when concentrated, and in a boiling state. Fine blue crystals, which are the *sulphate of copper*, are the result. This is what is commonly called *blue vitriol*. This salt is decomposed by iron; for if a piece of iron be immersed in a solution of sulphate of copper, the copper will be precipitated upon the iron. This process is often employed for procuring the copper from the water in copper mines, which has in it a large portion of sulphate of copper.

The muriatic acid does not act upon copper except in a state of ebullition, and then the *muriate* of copper is formed, which is of a green colour, and of an astringent taste. A solution of it is used as a sympathetic ink; for letters written with it will become yellow by warming, and will disappear again when cool.

The acetous acid in a sufficient degree of concentration dissolves copper, but when not concentrated, as in vinegar, it acts upon it very slowly, and forms common *verdigris*, which is an impure acetate of copper. This being dissolved in distilled vinegar, and subjected to evaporation, crystals are produced which constitute what is called *distilled verdigris*.

Copper is employed in making kitchen utensils; but as these vessels are liable to be corroded by the acids and fatty substances used in culinary preparations, they often become dangerous, as all the salts of copper are poisonous. Culinary utensils of copper should always be well tinned, but those of iron tinned are safer, as iron has no poisonous quality. The alloys of copper with other metals are very useful.

Tombac is formed of copper, arsenic, and tin.

Prince's metal, or *Pinchbeck*, is made of copper and zinc.

Brass is also formed of another proportion of copper and zinc.

Bronze is made of copper and tin.

Bell-metal is also of copper and tin, but with more tin than the latter alloy.

A solder for silver is made of copper and silver.

TIN.

Tin is a metal of a colour approaching to that of silver, but somewhat duller. It is extremely malleable. When hammered into leaves it constitutes *tin-foil.* It is not, however, very ductile. It is nearly as soft as lead, and may be easily bent, and then emits a crackling noise, which is peculiar to it.

Tin fuses more easily than any other metal: when it has been kept some time in a state of fusion, with access of air, its surface becomes wrinkled and covered with a grey pellicle, which is the *first,* or *grey oxide* of tin. This oxide when mixed with melted glass forms white enamel.

The grey oxide, when exposed to a greater degree of heat, takes fire, acquires more oxygen, and becomes of a pure white; the *white oxide* of tin.

Tin is not oxidized in the air at the common temperature; on account of which property, it is used for covering iron plates, to prevent their rusting.

Tin dissolves in the muriatic acid, forming *muriate of tin,* much used by dyers.

With nitric acid it forms *nitrate of tin.*

Tin united with sulphur forms the *aurum musium.* Alloyed with lead, it forms *plumber's solder.*

The best *pewter* is composed of tin alloyed with antimony, copper, and bismuth.

Tin is not found native, and its ores are not much distributed. The richest mines are in Cornwall.

LEAD.

This metal is never found in a native state. The ore from which it is chiefly procured is *galena,* which is lead united to sulphur, or a *sulphuret of lead.*

Pure lead is of a greyish colour. When fresh cut it is bright, but it soon tarnishes in the air. It stains the fingers or paper when rubbed on them. It is easily cut with the knife; has little or no elasticity, and is very malleable, but not very ductile. Water does not act upon lead. It easily fuses; and exposed to the air in a state of fusion, its surface becomes covered with a grey pellicle: if this be removed another succeeds, and in this manner the whole may be converted into a powdery substance. This pellicle is composed of oxide of lead mixed with a portion of metallic lead. If it be subjected to a strong heat, it is changed into a *yellow* powder, known by the name of *massicot;* which is the *first*, or *yellow oxide of lead:* it is used as a pigment.

If massicot be exposed to the flame of a furnace for some time, and kept stirred, it is converted into a beautiful pigment, called *minium*, or *red lead*. This has been called the red oxide of lead; but it is a mixture of the yellow oxide above mentioned, and another, the *brown oxide* of lead. This brown oxide may be procured by pouring nitric acid on red lead; when the yellow oxide in the red lead will be dissolved by the acid, and the brown oxide will remain, being insoluble.

If the oxides of lead be acted on by a strong heat, they give up their oxygen, and metallic lead remains; but they are more readily reduced by mixing them with combustible matter.

Lead, when procured from its ore, frequently contains so much silver, that the latter is worth extracting. This process is called *refining*. The lead is played upon by the flame of a furnace, by which the lead is oxidized, and the oxide is partly vitrified, and assumes a scaly form, called *litharge*. The silver then remains free.

The oxides of lead are easily changed into glass, and unite with all the metals except gold and silver; on this account they are employed for separating other metals from these. This process is called *cupellation.* The mixed metal is put into a dish called a *cupel,* made of bone-ashes, and placed in a cupelling furnace; the lead is oxidized and vitrified, and sinks into the bone-ash cupel, carrying with it all the baser metals.

White lead, so much used in painting, is a compound of the yellow oxide and carbonic acid; or a *carbonate of lead.* It is made by exposing plates of pure lead to the warm vapour of vinegar. By this they are gradually corroded, and converted into a heavy white powder, which is white lead.

When the carbonate of lead is dissolved in distilled vinegar, a salt is obtained, which crystallizes, and is called commonly *sugar of lead;* more properly *acetate of lead.* All the salts of lead have a sweetish taste, and are of a poisonous quality.

The affinity of the *muriatic acid* (hydrochloric acid) for the oxides of lead is so great, that the latter decomposes all the combinations of this acid. They decompose the muriate of soda (common salt), and thus form *muriate of lead,* which, on fusion, affords *mineral* or *patent yellow.*

Sulphuric acid does not act on lead when cold; but dissolves it at a boiling heat, and forms sulphate of lead, which is insoluble in water.

Chromate of lead, or chromic acid and lead, is a very beautiful yellow pigment. It is found native in small quantities, but is now prepared largely by art. Lead is one of the most useful metals. It is much employed in covering houses, when made into thin sheets by casting or by milling. It is used also for water-pipes and cisterns, and for a variety of well-known purposes. Its oxides are used in the manufactures of glass, and the glazings of earthenware; also as pigments. Preparations of lead are also used as external applications in diseases. The alloys of lead with tin form *solder*, and other alloys are employed in various arts.

ZINC.

This metal is chiefly procured from *calamine*, which is a *hydrated oxide of zinc;* and from *blende*, a sulphuret of zinc.

Zinc is a whitish metal of the colour of tin. It is slightly malleable when cold; but heated to between 200° and 300° it is very malleable, and has been manufactured into nails, drawn into wire, and made into sheets.

It is often known among workmen by the name of *Spelter*. It is easily fused, and is the most inflammable of the metals; thin leaves of it will take fire with the flame of a taper.

It is scarcely oxidized in the air at common temperatures, but is rapidly converted into oxide when kept melted in an open vessel. Its surface then becomes covered with a grey pellicle, which is *oxide of zinc*. When zinc is made red hot in an open vessel, it takes fire and burns with a brilliant flame, sending off white flakes of oxide. These have been called *flowers of zinc*.

Zinc decomposes water very slowly when cold; but with great rapidity when the vapour of water is brought into contact with it ignited.

Zinc dissolves very readily in diluted sulphuric acid; forming thus *sulphate of zinc*, or *white vitriol*. During this solution, a great quantity of hydrogen gas is disengaged, and this is one of the best modes of procuring that gas.

The nitric and muriatic acids also act upon zinc. Zinc combines with phosphorus and sulphur.

It can be alloyed with most of the other metals. With copper, it forms *brass*.

ANTIMONY.

Antimony is rarely found native. It is procured from an ore called *crude antimony*, which is a sulphuret of antimony.

Antimony is of a silvery white colour. It is so brittle, that it may be pulverised in a mortar; and its interior texture appears to be scaly or lamellar. It requires 800° to fuse it. It does not change in the air, but when kept in fusion at a red heat, it emits white fumes, consisting of an oxide formerly called *flowers of antimony*.

There are two oxides of antimony. The *protoxide* is procured by precipitating the muriate of antimony by potash. It is of a grey colour. The *peroxide* is formed by causing the nitric acid to act upon the metal, or by collecting the fumes already mentioned as the flowers of antimony. It is white. The oxides of antimony are very valuable medicines. Tartrate of potash and antimony form *emetic tartar*. *James's powder* is composed of phosphate of lime and antimony. *Kermes's mineral* is made from sulphuret of antimony by potash.

Antimony is also used in printers' types; and in specula for telescopes. The sulphuret has been used for staining hair black.

BISMUTH.

Bismuth is found native, and also combined with sulphur and arsenic.

It is of a reddish white colour, brittle, and easily fusible. It is not quite so hard as copper. It is not oxidated by water; it tarnishes in the air, but does not undergo any other change. Kept melted in an open vessel, its surface becomes covered with a dark grey pellicle, which is renewed till the whole is converted into oxide.

The *oxide of bismuth* is a yellow powder. When strongly heated it melts and becomes darker coloured.

Bismuth dissolved in the nitric acid, affords a white powder, if water be added to the solution. This is the *magistry of bismuth*, or *pearl white*, which has been used as a cosmetic, but very improperly, as it is apt to turn black by sulphuretted hydrogen.

Bismuth dissolved by the acetic acid forms a sympathetic ink. The characters written with it are invisible, until they are exposed to sulphuretted hydrogen, when they appear black.

Bismuth alloys with all the metals, and has the property of giving them great fusibility. If eight parts of bismuth, five of lead, and three of tin be fused together, they form what is called the *fusible metal*, which melts in boiling water. On this account bismuth enters into the composition of some of the soft solders.

It has also the property of rendering gold extremely brittle.

ARSENIC.

Arsenic, the poisonous effects of which are so well known, is a metallic substance, sometimes found native, but oftener combined with sulphur. The sulphuret of arsenic is called *orpiment.*

Arsenic is frequently mixed in metallic ores, and is driven off by heat. It is known by its peculiar smell, like garlic.

The colour of metallic arsenic is grey; it is very brittle. It soon loses its metallic lustre in the air, and becomes black. The oxides of arsenic have acid properties. There are two: the *white oxide of arsenic* is called arsenious acid. It is highly poisonous. It is soluble in water. It reddens vegetable blues. It is of a white colour, is semi-transparent, and brittle. Its taste is acrid, with a nauseous sweetness. The best way of getting rid of its action as a poison, when taken into the stomach, is to produce vomiting and purging.

Arsenic acid is a white deliquescent substance, of a sour taste, obtained by distilling nitric acid off metallic arsenic. It forms salts with several of the metals. Arseniate of iron crystallizes in cubes of a green colour. The arseniates of copper are among the most beautiful minerals. The alloys of arsenic with some of the metals are used for some purposes. It is mixed with lead to assist its granulation in making small shot. It is also used in making flint glass, and in calico-printing.

NICKEL.

Nickel is a rare metal. It is white, much resembling silver; and possesses, like iron, the magnetic property. It is not easily fused, and it is malleable. It is rather softer than iron, and soon tarnishes in the air. It is found native, and combined with arsenic.

Nickel dissolves in the acids, and its salts are distinguished by their fine green colour.

It forms two oxides, the *black* and the *grey*.

Nickel alloys with most of the metals, and it is found alloyed with iron in those masses that fall from the atmosphere, called *meteoric stones*. The origin of those lapideous masses that appear in so extraordinary a manner is entirely unknown: but the numerous well-authenticated accounts we have had of the fact put it now beyond dispute. They are first seen as large meteors, at a great height in the air, which suddenly burst with an explosion, and the fragments are seen to fall to the earth. It is very remarkable that their composition is always the same, although they have fallen at many different times, and in different places. They always contain native iron alloyed with nickel, in grains imbedded in a stony matter. The substance of these meteoric stones is not like any bodies which are found in the earth. In 1795, one weighing 56lbs. fell in Yorkshire.

MANGANESE.

This metal is never found native. Indeed its attraction for oxygen is so powerful, that it is with difficulty preserved in the metallic state. When pure, it is of a greyish colour, much like cast iron, and not malleable. It soon tarnishes, and at last becomes black. This change takes place more rapidly, if the metal be heated, or put into water.

There appear to be two oxides of this metal; the *protoxide*, which is of a greenish colour; and the *peroxide*, which is steel black, and has a considerable lustre: the latter is found in abundance, particularly near Exeter, and is much used in bleaching, and also for procuring oxygen gas, as it parts with it simply by the application of heat. It contains one-third of its weight of oxygen. This oxide is sometimes very beautifully crystallized. Manganese is also employed by glass-makers to destroy the greenish tint of glass, and for making violet-coloured glass.

Almost all the salts of manganese are soluble in water.

COBALT.

Cobalt is never found but in a state of combination. It is met with united to sulphur, arsenic, and other metallic substances.

The ores of cobalt had been long used for giving a blue colour to glass, before its metallic nature was known.

The metal itself is not applied to any use. When pure, it is a reddish grey colour; rather soft and brittle. Like iron, it is attracted by the magnet. It is not oxidized by the air nor by water. It is converted into a deep blue by exposure to heat and flame.

There are two oxides of cobalt. The *protoxide* may be formed by precipitating by potass, a solution of cobalt in nitric acid. It is of a blue colour when first precipitated, but becomes black by absorbing oxygen. To recover the blue colour, it must be heated red hot, by which the oxygen is expelled. This oxide dissolves in acids. The muriate of cobalt is green, and forms a sympathetic ink. Letters written with it are invisible, until they are warmed, and then they appear of a fine green; when cold they disappear again.

The *peroxide* of cobalt is procured by drying in the air, with heat, the protoxide just precipitated; by this the protoxide absorbs oxygen, and becomes the peroxide. It is black.

Ores of cobalt are very valuable. *Zaffre* is a substance produced by roasting the ores of cobalt, by which the volatile matters (generally arsenic and sulphur,) are driven off; the remainder is then fused with sand or pounded flints. A blue glass is thus formed, which, when ground and washed, constitutes the pigment called *smalt.*

MOLYBDENA.

Molybdena is found in nature combined with sulphur; forming the *sulphuret of molybdena*, which resembles plumbago in some of its properties. This mineral is of a bluish colour, more brilliant than plumbago, and makes on paper a trace of a grey tint. The metal has only been procured in small grains, which do not differ much in their properties from the sulphuret. It combines with oxygen, so as to form an acid called the molybdic acid. The *molybdate of lead* is a beautiful yellow mineral.

The *protoxide* of molybdena is a tasteless powder of a brown colour. Molybdena alloys with the other metals.

TUNGSTEN.

A mineral called *tungsten*, or *ponderous stone*, affords a peculiar metal. This metal is capable of being acidified, and when in this state it is joined to lime, it forms the tungstate of lime.

The metal when pure is much like steel, and is one of the hardest of the metals; a file can scarcely make any impression on it: it is also the heaviest, except gold and platinum. It is not used for any purpose.

When heated in an open vessel it is oxidized, and there are two oxides of tungsten. The *protoxide* is of a brown colour, and when heated it burns, and is converted into the *peroxide*, which is yellow, and has some of the properties of an acid, being capable of combining with salifiable bases.

The mineral called *wolfram* is composed of tungstic acid, manganese, iron, and tin.

OSMIUM.

This metal was discovered by Mr. Tennant, in the ore of platina. The metal is of a dark grey colour, and is oxidized when heated. Its oxide is volatile, and has a peculiar smell. It is little known, and has not been fused.

IRIDIUM.

This metal was also discovered by Mr. Tennant, in the ore of platina. It is of a whitish colour. It is fusible, and malleable. It unites with oxygen, and alloys with the metals. Its combinations are little known.

RHODIUM.

Dr. Wollaston discovered this metal in the ore of platina. It is very infusible, and forms malleable alloys with the malleable metals. It unites to oxygen like all the other metals, but is very little known.

PALLADIUM.

This metal was discovered by Dr. Wollaston, who found it in the ore of platina. Its colour is of a duller white than platina; it is malleable and ductile, and for fusion it requires a stronger heat than for gold. It is rather harder than iron.

It unites with sulphur, and is acted on by the acids, but most readily by the nitro-muriatic.

It forms alloys with other metals, that with gold has been usefully employed in astronomical instruments, as it is hard, and does not tarnish.

CADMIUM.

This metal was discovered by M. Stromeyer, in 1817, in ores of zinc, particularly in brown fibrous blende. It resembles tin, but is rather more fusible. It does not tarnish in the air.

It readily disolves in acids, but its salts are little known. It is a rare metal, and not applied to any use.

TELLURIUM.

This metal was discovered by Muller in 1782. It is of a bluish white colour, of considerable brilliancy. It is extremely brittle; melts in a heat a little greater than that required for lead. It is so volatile that it may be distilled like mercury.

Its oxide has acid properties. It is formed by burning the metal; a white smoke is disengaged, which is the oxide. It may be also obtained by dissolving the metal in nitromuriatic acid, and diluting the solution with a large quantity of water.

Tellurium combines with hydrogen, and with it forms a gaseous substance, called telluretted hydrogen.

This metal is scarce, and its combinations yet little known.

TITANIUM.

This metal is rare. It was discovered in a mineral, found in Cornwall, called *menachanite*. It was afterwards procured from another mineral, *titanite*, and some others. The metal when pure is brittle, very infusible, of a brass or copper colour, easily tarnishes in the air, and oxidizes by heat. There appear to be three oxides of titanium, the *blue*, the *red*, and the *white*.

The ores of titanium are either pure crystallized oxide, or the oxide united to iron, or to silex.

CHROMIUM.

This substance, little known in the metallic state, is important on account of the fine pigments it affords. It is capable of being acidified, and the chromic acid forms salts. The beautiful mineral called *red-lead of Siberia*, is a *chromate of lead*. This is now artificially prepared, and is a very valuable and beautiful yellow pigment. The chromic acid also unites to iron, the chromate of iron being found native; and it is from this that the chromic acid is procured and united to lead, to form the chromate of lead. Chromate of iron is, therefore, much sought after, and is found in greatest abundance in America, from whence our colour-makers chiefly procure it.

The pure metal is of a tin colour; it is very brittle, and is said to be magnetic. It is very infusible, and is not altered by the air, though when heated it is converted to an oxide.

Besides its acid, it seems to combine with oxygen in two other proportions, forming the *green* and *brown oxides.*

URANIUM.

This metal was discovered by Werner, in a mineral called *pechblende*, a blackish mineral resembling pitch.

Metallic uranium is brittle, and very infusible. It is of a grey colour. It is obtained with extreme difficulty, and little known.

Its oxide is greenish-yellow, and is found native, resembling green mica, and also in an earthy state.

COLUMBIUM.

This metal was discovered by Mr. Hatchet in analyzing an ore from North America. It has since been found in the minerals called *tantalite* and *yttro-tantalite.* The metal has been procured by Berzelius. It is of an iron colour, hard and brittle, and passes into an oxide at a red heat.

Its oxide is white. Its combinations are little known; but it is one of the acidifiable metals.

CERIUM.

This metal was lately discovered by Berzelius, in a mineral which has been called *cerite.* The characters of the metal are imperfectly known, as it has been scarcely seen. The oxide of cerium (cerite) is found native. There appear to be two oxides, the *white* and the *red.*

SELENIUM.

Selenium is a metal lately discovered by Berzelius in the sulphur of Fahhun, in Sweden. Its metallic lustre is considerable, and colour grey. It easily fuses and volatilizes before the blow-pipe, with a smell like horse-raddish. It alloys with the metals. It dissolves in nitric acid, and forms with it a substance which is considered as a new acid, *selenic acid,* which unites with alkalies, forming *seleniates.*

VEGETABLE SUBSTANCES.

Animals and vegetables differ essentially from minerals, in the two first possessing life and various organs fit for maintaining it, which is called *organic structure*. Through these organs, various juices and fluids circulate internally, and thus occasion the growth of the animal or plant. In mineral bodies this is not the case; they increase in size only by successive portions of matter adhering to the outside, nor is there any internal motion.

The principal ingredients of all vegetables are, oxygen, hydrogen, and carbon: sometimes they contain also a little nitrogen, and other elementary substances; and although these elements are few, yet, by many varieties in their proportions and modes of combinations, a great quantity of *proximate* constituents are produced.

Vegetable substances may be decomposed, or separated into their elementary principles by various means; by heats, by acids, and by fermentation: some of these processes occasion not only decomposition, but also new combinations of the elements that did not exist in the living bodies.

The principal substances of which all vegetables consist are,

Mucilage, or gum,
Sugar,
Fecula,
Gluten,
Fixed oil,
Volatile oil,
Resin,
Caoutchouc,
Woody fibre,
Colouring matter,
Tannin,
Wax,
Camphor,
Bitter principle,
Narcotic principle,
Vegetable acids.

Mucilage, or *gum.*—Various parts of vegetables impart to water, particularly if boiled with them, a certain viscous consistency: the substance so dissolved is called *mucilage.* Some trees suffer their mucilage to transude, either spontaneously or by incisions made in them. When it has become concrete by drying in the air, it is called *gum.*

Gum is soluble in water, but not in oils or alkohol, the latter of which precipitates it from its solution in water. It is insipid; it does not undergo any change by exposure to the air when dry. The gums of different trees differ considerably in their properties. *Gum arabic* may be considered as a very pure gum. *Cherry-tree gum* and *gum tragacanth* do not dissolve in cold water; but dissolve in boiling water, and, on cooling, assume the state of a jelly.

Gum consists of carbon, oxygen, and hydrogen.

Sugar.—The sugar in common use is extracted from a cane that grows only in warm climates, called the *sugar-cane;* but it may also be procured from all sweet vegetables. The American maple-tree affords a great deal of sugar, and this useful substance has been made from the beet-root, carrots, &c.

All sugars consist of carbon, oxygen, and hydrogen; but it appears that sugar from the cane contains more carbon than other sugars. That obtained from some vegetables will not crystallize. Sugar is first prepared in the countries where it is grown, by boiling the juice and evaporating; one part of the juice crystallizes, and forms the raw or muscovado sugar; the other part, the molasses or treacle, will not crystallize. The raw sugar when brought to this country is re-dissolved and crystallized again, which is called *refining*, by which the *loaf-sugar* is made. To whiten it completely, clay is put upon the tops of the conical pots in which the sugar has granulated, which allows water to percolate through, and thus drain off the last remains of the molasses. This is called claying the sugars.

Fecula, or *starch.*—This substance is contained in many seeds and roots. It is separated by bruising the vegetables containing it in water, and stirring them together. The fecula separates in the water, making it appear turbid. The white fluid is poured off and suffered to settle; the starch subsides to the bottom. Starch is made mostly from wheat; it is also made form potatoes. Starch is a white substance, insoluble in cold water, but soluble in warm. Its solution is gelatinous, and when solid it resembles gum: this, when dry, is a compound of starch and water. Starch is not soluble in alkohol.

In the process of converting grain into *malt*, the starch or fecula is changed into sugar. It may also be converted into sugar by boiling it with diluted sulphuric acid.

Starch consists of carbon, oxygen, and hydrogen.

Gluten.—This principle is found in various vegetable juices, but most abundantly in wheat flour. It is separated from it by washing, with a stream of water, a paste made of flour and water, at the same time kneading it between the fingers. The water carries off the starch gradually, leaving the gluten behind. Gluten is insoluble in water, and is elastic like elastic gum. It has no taste, and, when dried, becomes hard and brittle. It considerably resembles animal gluten, furnishing ammonia by distillation.

Fixed oil.—This is obtained by pressure from certain seeds and fruits, as the olive, linseed, rape seed, almond, &c. The fixed oils differ much; some being nearly solid, are called *vegetable butters*. When expressed, they are generally mixed with some mucilage, which occasions them to turn *rancid*. They may be deprived of their colour by charcoal. Fixed oils dissolve sulphur, and then form *balsams*. They also dissolve phosphorus.

Fixed oils are very combustible, and, when strongly heated, yield olifiant and carburetted hydrogen gases.

They form *soaps* by being combined with alkali. The best soaps are made of olive oil and soda; but common soaps are made with the animal oils and fat.

Transparent soap is made by dissolving soap in alkohol, and then concentrating the solution which is of a gelatinous consistence, by distilling off the alkohol.

Fixed oils are much used for painting, as they are of a drying nature: they are rendered still more drying by boiling them with the oxides of metals, as litharge.

Volatile oil.—This is also called *essential oil.* Many vegetables afford essential oil by expression, or by distillation. When dissolved in water they constitute *perfumed essences* and *distilled waters.* They have much odour and taste. They are inflammable. They are volatilized by a gentle heat, and evaporate entirely when pure so as to leave no trace. The chief essential oils are, the oils of turpentine, spike, cloves, oranges, lemons, lavender, &c. Many of them bear a high price.

Resin.—The resins are an important class of vegetable substances from their application in the arts. They are very numerous, and often exude spontaneously from trees. *Common resin* is obtained from the *fir*: a juice exudes from this tree, which is *common turpentine*: this consists of the oil of turpentine and resin. When the essential oil is separated by distillation, the resin remains. *Mastich* is a resin obtained from a tree that grows in Turkey. *Sandarach* is the resin of a tree in Barbary. *Copal* is a resin from a tree that grows in America, and is a very valuable substance for varnishes. *Lac* is a resin made by an insect in the East Indies. It is very useful in varnishes, and in sealing-wax. *Amber* is a substance resembling in its properties the resins, but it is only found in the earth, or washed out and driven on the shores. All the resins are insoluble in water, but soluble in alkohol, especially when assisted by heat. The greater number are soluble in the essential oils, and some are so in the fixed oils. They are also dissolved by alkaline lys, and by the acids. Resins consist of oxygen, carbon, and hydrogen; and they are supposed to be volatile oils saturated with oxygen.

Bitumen is a substance having some analogy with oils and resins, although differing in its constituents, and being also a mineral body. Pure bitumen is called *naphtha*, which is transparent, highly inflammable, volatile, of a pungent odour; it is found in certain wells, and there are springs of it in several parts of the world. When naphtha is exposed to the air, it thickens, and becomes dark coloured; it is then called *petroleum*, which is procured in the same manner, and is used for burning in lamps. *Maltha* or mineral pitch is a still farther thickened bitumen, and when it has become solid it is called *asphaltum*.

Caoutchouc.—This is the substance usually known by the name of *Indian rubber*, and sometimes *elastic gum*. It was first brought from South America. It exudes as a milky juice from a tree, which thickens and hardens by exposure to the air. The natives form it into bottles by covering balls of clay with this juice; the clay is afterwards washed out after the caoutchouc is solid. When caoutchouc is pure, it is white, the black colour being owing to the smoke used in drying it. This substance is extremely elastic. It is perfectly insoluble in water, but it may be softened by boiling, so that its edges may be united together. It is not soluble in alkohol: but it is soluble in ether; and when the ether is evaporated, the caoutchouc remains unaltered in its properties: by this means tubes and other instruments might be made of it, but the method would be too expensive. It is soluble in some of the fixed and essential oils, as in spermaceti and in oil of cajeput.

Woody fibre. — When a piece of wood has been boiled in water and in alkohol, until the soluble substances have been extracted from it, what remains insoluble is the woody fibre, or *lignin*, which is the basis of wood, and consists of long fibres, having a considerable degree of transparency, without taste, and unalterable by the air. It is insoluble in water and alkohol. It is very inflammable; and, when distilled in a close vessel, yields an acid substance formerly thought to be a distinct acid called the pyro-ligneous, but now known to be the acetic acid with an empyreumatic oil. Pure acetic acid or vinegar is now made from wood by distillation. Wood consists of oxygen, carbon, and hydrogen; when burned, the carbon remains, constituting *charcoal.*

Colouring matter. — The colours of vegetables are owing to peculiar matters, which are extremely numerous, and but little known. Many of them are used as dyes and pigments. The extraction of colouring matters from vegetables, and fixing them on cloths, constitute the arts of dyeing and calico-printing (which see). The colouring matters sometimes are inherent in gums, sometimes in resins, sometimes in fecula; consequently they require different chemical agents for their solution.

Tannin. — This principle is so called because it is employed in the art of *tanning* leather. It is also called the *astringent* principle. It is found abundantly in the barks of several trees, particularly the oak, and also in certain seeds. The gall-nut and grape-seeds afford very pure tannin; and a substance called *catechu*, from India, consists chiefly of it. Tannin is distinguished by its forming a precipitate with glue, or isinglass. This precipitate is insoluble in water, and is that which is formed when skins are tanned and made into *leather*.

Wax. — This substance appears to be formed by bees, by some animal process. It is also a vegetable substance, for the polish or varnish of leaves is owing to a coating of wax; and in some vegetables in Brazil wax exists in considerable quantity. Wax is insoluble in water, but sparingly dissolved by boiling alkohol. It is dissolved readily by the fixed oils, and then forms *cerates* and *ointments*. Wax contains a large proportion of carbon, with hydrogen and oxygen.

Camphor. — This substance is brought chiefly from Japan, and is distilled from a species of laurel. It is white and semitransparent; it is very inflammable, soluble in alkohol, and sparingly so in water. It is very volatile, and capable of converting into an acid, called the *camphoric acid*, which form neutral salts called *camphorates*. Camphor resembles essential oil in many of its properties.

Bitter principle. — It is supposed that this is a peculiar principle. It exists in many vegetables, particularly in quassia, gentian, hop, &c. When extracted, it is of a brownish yellow colour, and brittle when dry. Its taste is very bitter. It is soluble in water and alkohol. A variety of it is supposed to exist in unroasted coffee.

Narcotic principle. — This has lately been called *morphine*, and is found most abundantly in opium, which consists of this together with several of the principles which have been just described. It is a violent poison when taken internally. When pure it is white, without taste or smell. It is soluble in boiling alkahol, but is scarcely acted upon by water.

From the rapid progress of chemistry, many other vegetable substances are considered as peculiar principles; but it would exceed the bounds of this work to describe them all in detail. The chief among them are *suber*, or a peculiar substance found in cork; *asparagin*, found in asparagus; *medullin*, from the pith of the sunflower; *fungin*, the fleshy part of mushrooms, &c.

Vegetables also contain several acids ready formed. Vegetable and animal acids differ from the others essentially. They always contain carbon and hydrogen: some of them contain azote, and generally, though perhaps not always, oxygen. They do not seem capable of combining with different proportions of oxygen only, but whenever the quantity of this principle changes, that of the rest changes also.

Tartaric acid. — *Tartar*, or *cream of tartar*, is a substance found in an impure state, incrusted on the bottom and sides of wine casks: when purified by solution and filtration, it is sold for use. This salt, which is soluble in water, consists of tartaric acid and potash; it is therefore *tartrate of potash*. Tartaric acid when crystallized is imperfectly transparent, white, and does not deliquesce in the air. It is soluble in water. It combines with alcalies, earths, and metallic oxides, and forms *tartrates*.

Oxalic acid, so called from being first obtained from *oxalis acitosella*, or wood-sorrell. It is also called the *acid of sugar*, because obtained from sugar by the nitric acid. It is proper that every one should know that oxalic acid is a deadly poison, and that many persons have lost their lives by mistaking it for Epsom salts, which it resembles. It is much employed for cleaning boot-tops and leather, and also by the calico-printers.

Malic acid was first found in the juice of apples. It exists also in many other vegetables. This acid is very sour, and does not crystallize; it forms salts with many of the metallic oxides.

Gallic acid.—This acid is found in gall-nuts. It crystallizes, and forms whitish crystals, of a sour taste and peculiar smell. When gallic acid is put into a solution containing iron, a black precipitate appears. The base of ink is iron thus precipitated. To produce good black ink, infuse one pound of powdered gall-nuts for four hours, without boiling, in common water, with six ounces of gum-arabic, and six ounces of sulphate of iron. With gold, gallic acid forms a brown precipitate; with silver, a grey; with mercury, an orange; with copper, a brown; and with lead, a white.

Citric acid is procured from the juice of lemons and other fruits. It is capable of crystallizing. Its crystals are soluble in water, and very sour. It forms *citrates* with the earths, alkalies, and metals. It is much used in calico-printing. It is also used for discharging spots of ink from linen.

Benzoic acid is obtained from gum-benzoin, or benjamin. It is a crystallizable acid. The compounds which it forms are called *benzoates*.

Kinic acid is found in Peruvian bark.

FERMENTATION.

If *mucilaginous saccharine* vegetable substances be subjected to the action of water and heat, (from 60 to 70 deg. Fahr.) they experience, in a very short time, a very striking change. An internal commotion takes place, the mass grows turbid, a large quantity of air-bubbles, consisting of carbonic acid gas, are disengaged, which, on account of the viscidity of the matter in which they are inclosed, form a stratum on the surface of the fluid, known by the name of *yeast*. After a time these appearances cease, the fermented liquor becomes clear and transparent, and no more gas is discharged. The liquor now has lost its sweetness and viscidity, and has acquired the vinous taste and intoxicating quality. Sugar appears to be essential to this process; and all mucilaginous substances containing sugar are capable of this fermentation, which is called the *vinous*.

Wine is made in this manner from the juice of the grape; if the fermentation be checked when at its height, by excluding the air, the wine begins to ferment anew, and effervesces when again exposed to the air. The sparkling wines, as Champagne, are prepared in this manner, and hence should be considered as imperfect wines.

To prepare vinous liquors from grain or corn, it must first be converted into *malt*, by steeping it in water, and then exposing it to the air, turning it frequently over; by this process, the gluten of which the *germ* consists is separated, and the fecula is converted into sugar by the germination of the seed.

Beer is made by boiling the malt in water, which produces a sweet liquor called *wort;* this is converted into beer by fermentation and the addition of hops, which furnish a bitter substance.

Wine, beer, and all fermented liquors, owe their intoxicating qualities to a peculiar substance which they contain, and which is the produce of fermentation alone. This substance is a fluid called *alkohol*, or *spirit of wine*, and may be separated in a pure state by distillation. When first obtained it is mixed with a quantity of water, but if it be redistilled, it is obtained very pure, and is then called *rectified alkohol*. Alkohol is of a strong heating taste, of a peculiar penetrating odour, and it is very inflammable and volatile. It dissolves resins, essential oils, camphor, sulphur, phosphorus, &c. It is composed of hydrogen, carbon, and a small quantity of oxygen.

Strong acids and alkohol have a considerable action on each other, and this produces *ether*, which is a fluid still more highly volatile, inflammable, and odorous. Nitric acid with alkohol produces *nitric ether*, and sulphuric acid in the same way produces *sulphuric ether*.

When wine, or any fermented or vinous liquor is exposed to a heat, from 75° to 85° Fahr., and access of air is permitted, the fluid becomes turbid, and a new change of principles takes place. It loses its taste and smell, it becomes sour, and is converted into *vinegar*, or *acetous acid.* Though vinegar is chiefly prepared from fluids which have undergone the vinous fermentation, yet this is not necessary to the production of vinegar, for simple mucilage is capable of passing into the state of *acetous* fermentation. When the saccharine principle predominates in any substance exposed to the necessary conditions of fermentation, alkohol is produced; when mucilage is most abundant, vinegar or acetous acid is the product; and when gluten is predominant, ammonia will be discovered, and *putrefaction* will take place.

Common vinegar may be purified, or concentrated by distillation, and it is then called *distilled vinegar*. This, however, still consists of the *acetic acid* and water. To free the acid from the water, distilled vinegar is saturated with some metallic oxide, and an acetate is thus formed. The acetate is then heated red hot in a retort, by which it is decomposed, and the acetic acid passes over pure.

Acetate of copper or *verdigris*, and likewise *acetate of lead*, are used for this purpose. Acetic acid is very pungent and caustic. It is very volatile, and combines with the metals, earths, and alkalies.

This acid may also be obtained from wood, by subjecting it to distillation in a retort. In this state it is very impure, being combined with a quantity of empyreumatic oil. This was formerly called *pyroligneous acid*. When separated from impurities it is essentially the same with vinegar, and is now employed for the same purpose.

The last change, or final decomposition that vegetables undergo, is called the *putrefactive fermentation*, or *putrefaction*. Without moisture, heat, and a due access of air, this does not take place. By this vegetables are resolved into their constituent principles, and *ammonia* is formed.

ANIMAL SUBSTANCES.

The elementary principles of animal substances are nearly the same with those of vegetables, but the former contain more nitrogen and phosphorus, and the latter more carbon and hydrogen.

The *proximate constituent parts* of animal substances are the following:

Gelatine, or *animal jelly*, is very generally dispersed through all the parts of animals, even in bones, but exists in the greatest quantity in the tendons, membranes, and the skin. It is a viscid substance, very soluble in warm water, but not in alkohol; insipid, and without smell; when cold, it congeals into a cohesive, tremulous substance. It forms the basis of soups, broths, &c. and imparts to them their nutritious qualities. When evaporated to dryness, it forms *portable soup*, *size*, *glue*, &c. The union of this latter substance in the skin with tannin constitutes *leather*. *Isinglass* is gelatine procured from certain parts of several fish, particularly the sturgeon. The *tendons* and *membranes* of the body are chiefly gelatine.

Fibrin, or *animal fibre*, forms the basis of the muscular, or fleshy parts of animals. It is there combined with albumen, and remains with it after all the soluble parts of the flesh have been separated by water. It may also be obtained from *blood*, by washing the *clot* or *coagulum* in water, till a white fibrous matter remains. Fibrin is not soluble in cold water, but is very slightly so in boiling water. It is soluble in acids and alkalies, and by its union with the latter a *soap* is formed. Chaptal employed this property to make a soap from wool. It is very analogous to vegetable gluten.

Albumen is the principal constituent of the serum of blood, and is also called *coagulable lymph*. The white of eggs consists almost entirely of albumen. It is miscible with cold water, but is coagulated by heat, which forms the best test of its presence. It is also coagulated by acids and alkohol.

Mucus.—This substance in animals appears intended to lubricate or smooth certain parts of the body, and seems very analogous to a solution of gum. However, Dr. Bostock has shown that it differs from gelatine, as it cannot in cold water be brought to assume the gelatinous state. Tannin precipitates gelatine, but not mucus, whereas subacetate of lead, (extract of Goulard,) forms a precipitate with mucus, but not with gelatine. Mucus is found in saliva, tears, in the intestines, joints, &c.

Oil.—Animal oils are fat, tallow, butter, &c. They are mostly solid at the usual temperature. They may be rendered fluid by heat. Oil is obtained in great quantities from certain fish, particularly the whale, seal, &c. and fish oil continues fluid. It is very similar to vegetable oil in its other properties. *Spermaceti* somewhat resembles wax, and is obtained from the head of a species of whale. Animal fibre may be converted into a substance like spermaceti by treatment with the nitric acid, or by exposing it to a current of running water for several months. This has been called *adipocire*. It has been shown lately that fat is a compound body, consisting of a substance solid and much like wax, which has been called *stearin*, and a fluid oil called *elain*.

Milk is a substance secreted by certain animals for the nourishment of their young. As is well known, milk on standing for a day throws up cream to the surface. Cream has much of the properties of an oil, and when agitated by churning, *butter* is separated from it. If milk stands until it becomes sour, it separates into a coagulum and a whey. This change may be more completely effected by adding to the milk a small quantity of certain substances, as acids, or *rennet*, procured by boiling in water the inner coat of the stomach of a calf. The coagulum is thus made more solid, and when pressed and dried it forms *cheese*.

In animal bodies there are also found several peculiar acids.

The *lactic acid* is found in sour whey. It combines with the earths and alkalies, forming salts called *lactates*. It resembles much the acetic acid.

The *uric acid* is found in *urine*. The substance voided with the urine called *gravel*, and also those stones formed in the bladder called *calculi*, are almost entirely composed of uric acid. This acid, however, exists in urine even in its most healthy state.

The *amniotic acid* is found in the liquor of the amnios of a cow. It separates in white crystals.

The *saccho-lactic acid* is formed by acting on sugar of milk, or on gum by the nitric acid. It forms salts called *saccho-lactates.*

The *sebacic acid* is procured from animal fat. It becomes solid, is of a white colour, with a taste slightly acid.

The *Prussic acid* has been described, p. under the name of the *hydrocyanic acid.*

The *formic acid* is an acid procured from ants.

Animal resins.—Peculiar resins have been found in certain animal substances, as in the *bile*, *ambergris*, &c.

Animal sugar is found in milk, also in the urine in certain diseases. It is similar to common sugar.

Blood, when suffered to rest, separates into two parts; the one a coagulum or clot, called the *crassamentum ;* the other, a fluid called the *serum.* The crassamentum consists of fibrin mixed with albumen and colouring matter. The colouring part of blood consists of extremely minute globules of a red colour, which float in the serum, and may be seen by the microscope. The red colour of blood has been supposed to be owing to iron which was oxydated by the air in the lungs, but this theory is now rendered questionable. The serum is composed of albumen, and also contains a small portion of alkali and other substances. It is coagulated by heat, the acids, and alkohol.

Bone is composed of gelatine, another substance which seems to be analogous to cartilage or coagulated albumen, an oil, or marrow, and phosphate and carbonate of lime, besides other matters in minute portions.

Teeth are composed of similar ingredients.

Shells contain a greater proportion of carbonate of lime.

Horns, *nails*, *hoofs*, and *quills* are chiefly gelatine and albumen.

Besides the animal substances above enumerated, there are various matters *secreted* or formed by certain organs in the body, as *saliva*, the *gastric juice*, the *bile*, the *fluid of perspiration*, &c., the nature of which is not yet thoroughly known.

The examination of animal substances, called *animal chemistry*, is one of the most difficult, as well as one of the most important, branches of the science; and a wide field is yet open for research.

When animal bodies are deprived of the vital principle, and are exposed to the air, they undergo a speedy decomposition called *putrefaction*. By this they are resolved partly into their elementary principles, and some of these form new compounds. The first change is observed by the bodies altering in their colour, losing their elasticity, and by their giving out a very fetid and noxious smell. The greater part, in time, assumes a gaseous form, and nothing remains but a small quantity of earths and salts.

One of the greatest improvements in chemistry has been that made in its *nomenclature*, which we owe chiefly to the French chemists. As the former names of many substances differ so entirely from those at present employed, that, without some assistance, many of the old writers on chemistry are not now intelligible to those acquainted only with the modern nomenclature, a list is subjoined of the terms which most generally occur in old books on this subject, together with those which are now adopted instead of them.

Old Names arranged Alphabetically.	*New Names.*
Acetous salts	Acetates
Acid of vitriol, phlogisticated	Sulphureous acid
— of alum	Sulphuric acid
— of vitriol	
— of vitriolic	
— of sulphur	
— of nitre, phlogisticated	Nitrous acid
— of nitre, dephlogisticated	Nitric acid
— of saltpetre	
— of sea salt	Muriatic acid
— marine	
— aerial	Carbonic acid
— of chalk	
— cretaceous	
— of charcoal	
— mephitic	
— of spar or fluor	Fluoric acid
— sparry	
— of borax	Boracic acid
— of arsenic	Arsenic acid
— of tungsten	Tungstic acid
— of wolfram	
— of molybdena	Molybdic acid
— of apples	Malic acid
— of sugar	Oxalic acid
— saccharic	
— of lemons	Citric acid
— of tartar	Tartareous acid
— of benzoin	Benzoic acid
— of galls	Gallic acid
— of amber	Succinic acid
— of ants	Formic acid
— of phosphorus phlogisticated	Phosphorus acid
— of phosphorus dephlogisticated	Phosphoric acid

Old Names arranged Alphabetically.	*New Names.*
Acid of fat — sedative	Sebacic acid
— of lac	Laccic acid
— of milk	Lactic acid
— of the sugar of milk	Saccho-lactic acid
Air	Gas
— dephlogisticated — empyreal — vital — pure	Oxygen gas
— impure, or vitiated — burnt — phlogisticated	Nitrogen, azote, or azotic gas
— inflammable	Hydrogen gas
— marine acid	Muriatic acid gas
— dephlogisticated — marine acid	Oxygenated muriatic acid gas, or chlorine
— hepatic — fetid of sulphur	Sulphureted hydrogen
Air fixed — solid of Hales	Carbonic acid gas
— alkaline	Ammoniacal gas
Alkalies, fixed	Potash and soda
——— volatile	Ammonia
——— concrete volatile	Carbonate of ammonia
——— caustic	Pure alkalies
——— effervescent, aerated, or mild	Alkaline carbonates
——— vegetable	Potass
——— mineral or marine	Soda
——— Prussian	Prussiate of potash
Alum	Sulphate of alumine and potash
Antimony, crude	Sulphuret of antimony
Aqua fortis	Nitric acid of commerce
—— regia	Nitro-muriatic acid
—— ammonia pura	Ammonia
Argil, or argillaceous earth	Alumine, or alumina
Bezoar mineral	Oxide of antimony
Black lead	Plumbago
Borax	Borate of soda
Butters of the metals	Muriates of the metals
Calces, metallic	Metallic oxides
Ceruse	Carbonate of lead

Old Names arranged Alphabetically.	*New Names.*
Ceruse of antimony	White oxide of antimony
Charcoal, pure	Carbon
Colcothar of vitriol	Red oxide of iron by the sulphuric acid
Copper, acetated	Acetate of copper
Copperas, green	Sulphate of iron
——— blue	——— of copper
Cream of tartar	Acidulous tartrate of potash
Earth, calcareous	Lime
—— aluminous	Alumina, or alumine
—— siliceous	Silex
—— ponderous	Barytes
—— magnesian, or muriatic	Magnesia
Emetic tartar	Antimoniated tartrate of potash
Essences	Volatile oils
Ethiops, martial	Black oxide of iron
—— mineral	Black sulphureted oxide of mercury
Flowers, metallic	Sublimated metallic oxides
—— of sulphur	Sublimated sulphur
Fluors	Fluates
Hepars	Sulphurets
Heat, latent	Caloric
Kermes mineral	Red sulphureted oxide of antimony
Lapis infernalis	Fused nitrate of silver
Leys	Solutions of alkalies
Liquor silicum —— of flints	Solution of siliceous potash
Litharge	Semivitreous oxide of lead or litharge
Liver of sulphur, alkaline	Sulphuret of potash
——— calcareous	—— of lime
Luna cornea	Muriate of silver
Magistery of bismuth	Oxide of bismuth by the nitric acid
Magnesia alba ——— aerated	Carbonate of magnesia
——— black	Black oxide of manganese
Masticot	Yellow oxide of lead
Mephitis	Nitrogen gas
Minium	Red oxide of lead
Mother waters	Saline residues
Nitre, or saltpetre	Nitrate of potass

Old Names arranged Alphabetically.	*New Names.*
Nitres	Nitrates
Oils, fat	Fixed oil
—— etherial	Essential oils
—— of tartar per deliquium	A solution of potash
Phlogiston	A principle imagined by Stahl, but now not admitted
Phosphoric salts	Phosphates
Precipitate, red	Red oxide of mercury by the nitric acid
———— *per se*	Red oxide of mercury by fire
Principle, astringent	Gallic acid
———— tanning	Tannin
———— acidifying	Oxygen
———— inflammable	See Phlogiston
Pyrites of copper	Copper pyrites
Pyrites martial	Iron pyrites, or sulphuret of iron
Realgar	Red sulphuretted oxide of arsenic
Regulus of the metals	The metals in a pure state
Rust of iron	Oxide of iron
Saffron of Mars	Oxide of iron
Sal ammoniac	Muriate of ammonia
— polychrest	Sulphate of potash
Salt, common or sea	Muriate of soda
— febrifuge of Sylvius	Muriate of potash
— fusible of urine	Phosphate of soda
— Glauber's	Sulphate of soda
— Epsom	——— of magnesia
— of sorrel	Acidulous oxalate of potash
— of wormwood	Carbonate of potash
— vegetable	Tartrite of potash
Saltpetre	Nitrate of potash
Selinite	Sulphate of lime
Spar, calcareous	Crystallized carbonate of lime
—— fluor	Fluate of lime
—— ponderous	Sulphate of barytes
Spirit, ardent —— of wine	Alkohol
—— of nitre	Nitric acid
———— fuming	Nitrous acid
—— of salt	Muriatic acid

Old Names arranged Alphabetically.	*New Names.*
Spirit of sal ammoniac -	Ammonia
—— of vitriol -	Sulphuric acid
Spiritus rector -	Aroma
Sublimate, corrosive	Muriate of mercury
Sugar of lead -	Acetate of lead
Tartar - -	Acidulous tartrite of potash
—— emetic -	Antimoniated tartrite of potash
—— vitriolated -	Sulphate of potash
Tartars - -	Tartrites
Tinctures, spirituous	Resins dissolved in alkohol
Turbeth mineral -	Yellow oxide of mercury by the sulphuric acid
Vinegar, distilled —— radical	Acetic acid
Vitriols - -	Sulphates
Vitriol, blue -	Sulphate of copper
—— green -	—— of iron
—— white -	—— of zinc
Water acidulated -	Water impregnated with carbonic acid gas
—— hepatic -	Water impregnated with sulphuretted hydrogen

MANUFACTURES AND ARTS.

THE modern sciences, and particularly chemistry, have been of late successfully applied to the improvement of several of the useful arts; and some, in consequence, have undergone almost an entire change. Of the principles of some of them we propose to give a brief description.

MAKING BREAD.

Scarcely any nation exists, in which the use of bread is entirely unknown, or something as a substitute for it; a dry food appearing to be necessary to promote the secretion of saliva, in the process of mastication.

In Lapland, where they have no corn, they make a kind of bread from dried fish, and of the inner rind of the bark of the pine. In some parts of America, they use, for this purpose, casava, the root of a plant which is poisonous till it is rendered wholesome by the extraction of its acrid juice. In the South Sea islands, the bread-fruit tree affords the natives a substance resembling bread.

From time immemorial, the farinaceous seeds have been employed as food, and they are the most nutritive of all the vegetables. Few of the alimentary substances are used by man in a raw and crude state; almost all undergo some preparation, by which they are rendered more easy of digestion, or are more palatable. The application of heat generally effects considerable changes in the different principles of which they are composed. Thus, bread from wheat is no longer capable of forming a paste with water, such as can be made with flour; nor can starch, and gluten, elements existing in flour, be obtained from it after it has been baked in bread. The alteration in potatoes by the culinary process is even more considerable.

The farinaceous vegetables used for making bread, are chiefly wheat, barley, oats, rye, buck wheat, maize, beans, pease, rice, potatoes, &c. In times of scarcity, other substances have been used, as acorns, chesnuts, &c.

Of all these wheat is found to afford the best bread, and we shall begin by describing it. Wheat flour, when analysed, is found to consist of— 1. Gluten. 2. Fecula, or starch. 3. Saccharine matter, or mucilage.

The *gluten* is very elastic, of a greyish white colour, and when drawn out to its fullest extent, has the appearance of animal membrane. In this state, it adheres to many bodies, and forms a very tenacious glue, which has been used for mending broken porcelain. It is insoluble in water, alkohol, ether, or oil; and, in many of its properties, it resembles animal substances.

The *fecula* is a delicate white powder, soft to the touch, scarcely sensible to the taste, almost insoluble in cold water, but soluble in warm water.

The *saccharine* part is a sugar similar to what is contained in other vegetables.

These three constituent principles are easily separated from each other in the following manner. Knead some flour with water, and let a stream of water constantly flow over it. The fecula, or starch, will be carried off by the water, and will fall to the bottom of the vessel where it is collected; the sugar will be held in solution in the water employed, and the gluten will remain alone.

There are three sorts of bread in general use, prepared from wheat flour: 1. Unleavened bread. 2. Leavened bread. 3. Bread made with yeast.

Unleavened Bread.

When flour is kneaded with water, it forms a tough adhesive paste, containing the constituent principles of flour, with little or no alteration, and not easily digested by the stomach.

When formed into cakes, and baked by heat, the gluten, and probably the starch, undergo a considerable change, and the compound is rendered more easy of digestion.

Bread made in this manner, without any addition, is called unleavened bread. It is not porous, but solid and heavy.

This is, no doubt, the most ancient method of preparing bread, and it is still used in many countries. The oat cakes, and barley bread, used in Scotland, and the north of England, are of this kind; so are also biscuits of all kinds.

Unleavened bread is also used by the Jews during the Passover.

Of Leavened Bread.

When flour is kneaded with water, it is called *dough;* and when this is kept in a warm place, it swells up, becomes spongy, and is filled with air-bubbles; it disengages at length an acidulous and spiritous smell, tastes sour, and in this state is called *leaven.*

Here the saccharine part has been converted into ardent spirit, the mucilage tends to acidity, and the gluten probably verges towards a state of putridity. By this incessant fermentation, the mass is rendered more digestible and light, that is, it becomes much more porous by the disengagement of elastic fluid, which separates its parts from each other, and much enlarges its bulk. The operation of baking puts a stop to this process, by evaporating a great part of the moisture, which favours the chemical attractions, and probably also by further changing the nature of the component parts. Bread, however, in this state, will not possess the requisite uniformity. In order to promote an uniform fermentation, a small portion of leaven is intimately blended with a quantity of other dough, which, by the aid of heat, diffuses itself, and causes all the parts to ferment at the same time. As soon as the dough has acquired a sufficient bulk from the extrication of carbonic acid gas, it is considered as fit for the oven. It will be necessary here to consider more at large the nature of the *fermentation*, which is so essential in the making of good bread.

When wheat-flour and water are mixed, the saccharine extract of the flour, in consequence of heat and moisture, has its constituent principles disunited; the oxygen seizes the carbon, forming carbonic acid, which flies off in the form of gas, and occasions that internal motion and increase which appears. This process, if left to itself, is extremely slow, and is therefore accelerated by the addition of more dough and warm water. The gluten, being dispersed through every part of the mass, forms a membrane among the dough, which suffers the carbonic acid gas to expand, but prevents its total escape, thus causing that porous reticulated appearance, which fermented bread always has. As soon as the dough begins to sink, it is made up into the proper form, and put into the oven, where the heat converting the water into an elastic vapour, the loaf rises still more. The fermentation by means of leaven is thought to be of the acetous kind, because it is generally so managed that the bread has a sour taste.

Bread made with Yeast.

Yeast is the froth formed upon the surface of beer, or ale, in a state of fermentation, and is composed of carbonic acid gas inclosed in bubbles of the mucilaginous liquor. When this is mixed with dough, it causes it to ferment, and rise better and more quickly than ordinary leaven; and by this means the best bread, and that now most generally in use, is made.

Bread made with yeast is not only less compact, lighter, and of a much more agreeable taste than the preceding kinds; but it is also more miscible in water, with which it does not form a viscous mass, a circumstance of the greatest importance in digestion.

Bread, if well baked, is materially different from flour and farinaceous cakes; it no longer forms a tenacious dough with water, nor can starch or gluten be any more separated from it: and hence most probably its good qualities result.

The method of making *common family bread* is as follows: to half a bushel of flour add six ounces of salt, a pint of yeast, and six quarts of water that has boiled; in warm weather pour the water in nearly cold, but it winter let it be lukewarm. Put all these into a kneading-trough, and work them together till they are the proper consistence of dough. Cover up the dough warm that it may ferment and rise. This is called *setting the sponge.* After letting it lie the proper time, an hour and a half, more or less, knead it well together, and let it lie some time longer covered up. The oven must in the mean time be heated: when this is done, and it is properly cleaned, make the bread into loaves, and place them in the oven to bake.

Household bread, or *brown bread*, is baked in the same manner, only of flour that is made from the whole of the wheat, the bran as well as the flour being ground together; whereas in the white bread, the coarser part of the bran is separated from the flour. In what is called *French bread*, the fermentation is carried on longer than in common bread, by which it becomes more porous, and consequently lighter. Some bakers make a superior kind of French bread, by putting together a peck and a half of the finest wheaten flour, called Hertfordshire white, a pint of milk, a quarter of a pound of salt, a pint and half of yeast, a quarter of a pound of butter, two eggs, and three quarts of water; it is baked nearly in the same manner, only frequently turning the bread in the oven.

The process used by the bakers for making bread varies from what has been described, only in circumstances depending on the great quantity that is baked at a time. It is said that they are apt to adulterate the bread sometimes with alum, and also with chalk, and for this they are severely punishable; and any one suspecting it may easily detect it by cutting a loaf in slices, and mixing it with water which will dissolve the alum: and it may then be obtained by evaporation.

Bread is made from the farinaceous grains; but of these, barley, oats, and rye, are most generally used in Great Britain next to wheat. Wheat alone possesses the gluten above described, which is so useful in making the bread porous and light; on which account it is more difficult to make fermented bread from the other grains: but this difficulty is obviated by adding to them a small quantity of wheat flour, and many of them afford bread nearly as nutritious, if not entirely so, as wheat. It appears to be the fecula, or starch, that is the the most nutritive part of the grain; the potatoe, which contains a great proportion of this substance, forms the food of the most of peasantry in Ireland.

Rye bread is of a brownish colour, and has rather a sweetish taste. It is much used in the north of Europe, and also in some parts of this kingdom; but it is more usually mixed with a quantity of wheaten flour.

Rye is also sometimes mixed with a fourth part of ground rice, and makes a good and economical household bread.

Bread has also been made by mixing *turnips* and flour in equal quantities. This requires rather longer baking, and has at first a sweet taste, which it loses on being kept twenty-four hours.

Rice, though usually prepared for food by boiling, has been made into bread by mixing with it a little flour, or potatoes.

Potatoes have also been made into bread by mixing with them a quantity of wheaten flour.

BREWING.

The art of brewing, or of preparing a fermented liquor called *beer*, from farinaceous seeds, is very ancient. It was known to the ancient Egyptians, Spaniards, Germans, Gauls, inhabitants of the British Isles, and of the north of Europe. The liquor made by them, however, resembled more our sweet and mucilaginous ales, the use of hops being of modern invention.

Beer is made of an extract produced from malt and hops by boiling; and this extract is afterwards fermented by adding yeast to it.

Malt is made from barley by a process which is called *malting*. Barley is a grain consisting of fecula, or starch, albumen, and a little gluten. By the process of malting, its fecula is converted into sugar, a substance essential to the production of ardent spirit or alkohol, which is the substance that gives the intoxicating quality to every liquor. To prepare malt, the grain is put into a trough with water, to steep for about three days; it is then laid in heaps, to let the water drain from it, and afterwards turned over and laid in new heaps. In this state, the same process takes place as if the barley were sown in the ground; it begins to germinate, puts forth a shoot, and the fecula of the seed is converted into saccharine matter. When this is sufficiently accomplished, which is known by the length of the shoot, (about ⅔ of the length of the grain) this process of germination must be stopped, otherwise the sugar would be lost, nature intending it for the nourishment of the young plant. The malt is, therefore, spread out upon a floor, and frequently turned over, which cools it, and dries up its moisture, without which the germination cannot proceed. When it is completely dried in this manner, it is called *air-dried* malt, and is very little altered in colour. But when it is dried in kilns, it acquires a brownish colour, which is deeper in proportion to the heat applied; it is then called *kiln-dried*. This malt is then coarsely ground in a mill.

The quality of the beer depends upon the way in which the malt has been prepared as well as the quantity. There are three kinds of malt generally used, *pale*, *brown*, and *amber*. Pale malt is dried by a slow fire, and only so much as just to check the future germination of the grain: it is dried sometimes upon hair or wire sieves, which are made to form the bottom of the kiln. Brown malt is dried with a quick fire, and the outside is in fact a little charred. Amber malt is intermediate between these two.

Pale malt is used for fine ales and pale beer: brown malt is used for porter; and amber is employed for brown ale and beer, and also to mix with brown malt for porter, a practice which many prefer.

Mashing is the next step in the process of brewing. This is performed in a large circular wooden vessel called the mash-tun, shallow in proportion to its extent, and furnished with a false bottom, pierced with small holes, and fixed a few inches above the real bottom. There are two side openings in the interval between the real and false bottom: to one is fixed a pipe, for the purpose of conveying water into the tun, and the other is for drawing the liquor out of it. The malt is to be strewed evenly over the false bottom of the same tun, and then, by means of the side pipe, a proper quantity of hot water is introduced from the upper copper. The water rises upwards through the malt, or, as it is called, the *grist*, and when the whole quantity is introduced, the mashing begins, the object of which is to effect a perfect mixture of the malt with the water, so that the soluble parts may be extracted by it: for this purpose, the grist is sometimes incorporated with the water by iron rakes, and then the mass is beaten and agitated by long flat wooden poles, resembling oars, which are either worked by the hand or by machinery.

When the mashing is completed, the tun is covered in, to prevent the escape of the heat, and the whole is suffered to remain still, in order that the insoluble parts may separate from the liquor: the side pipe is then opened, and the clear wort allowed to run off, slowly at first, but more rapidly as it becomes fine, into the lower or boiling copper.

The chief thing to be attended to in mashing is the temperature of the mash, which depends on the heat of the water, and the state of the malt. If the water was let in upon the grist boiling hot, the starch which it contains would be dissolved, and converted into a gelatinous substance, in which all the other parts of the malt, and most of the water, would be entangled beyond the possibility of being recovered by any after-process.

The most eligible temperature appears to be from 185° to 190° Fahr.; for the first mashing, the heat of the water must be somewhat below this temperature, and lower in proportion to the dark colour of the malt made use of. For pale malt the water may be 180°, but for brown it ought not to be more than 170°.

The liquor, or wort, as it is called, of the first mashing, is always by much the richest in saccharine matter; but to exhaust the malt, a second and third mashing is required, in which the water may be safely raised to 190°, or upwards.

The proportion of wort to be obtained from each bushel of malt depends entirely on the proposed strength of the liquor. It is said that twenty-five or thirty gallons of good table beer may be taken from each bushel of malt. For ale and porter of the superior kinds, only the produce of the first mashing, or six or eight gallons, is to be employed.

Brewers make use of an instrument called a *sacchrometer*, to ascertain the strength and goodness of the wort. This instrument is a kind of hydrometer, and shows the specific gravity of the wort, rather than the exact quantity of saccharine matter which it contains.

The next process in brewing is *boiling* and *hopping*. The hop plant is well known: hops contain an aromatic and essential oil, having an agreeable bitter flavour. Hops are necessary to prevent the beer from passing into the acetic fermentation, which would take place after the vinous fermentation had ceased. They check the fermentation in a great degree, so as to occasion it to go on slowly, and thus to acquire strength; and the quantity of hops depends upon the length of time the beer is intended to be kept. Hops are best when new, as they lose much of their flavour by keeping.

If only one kind of liquor is made, the produce of the three mashings is to be mixed together; but, if ale and table beer are required, the wort of the first, or first and second mashings, is appropriated to the ale, and the remainder is set aside for the beer.

All the wort destined for the same liquor, after it has run from the tun, is transferred to the large lower copper, and mixed with a certain proportion of hops. The better the wort, the more hops are required. In private families a pound of hops is generally used to every bushel of malt; but in public breweries, a much smaller proportion is deemed sufficient. When ale and table beer are brewed from the same malt, the usual practice is to put the whole quantity of hops in the ale wort, which, having been boiled some time, are to be transferred to the beer-wort, and with it to be again boiled.

When the hops are mixed with the wort in the copper, the liquor is made to boil, and the best practice is to keep it boiling as fast as possible, till upon taking a little of the liquor out, it is found to be full of small flakes like that of curdled soap. The boiling copper is, in common breweries, uncovered: but in many, on a large scale, it is fitted with a steam-tight cover, from the centre of which passes a pipe, that terminates by several branches in the upper, or mashing copper. The steam, therefore, produced by the boiling, instead of being wasted, is let into the cold water, and thus raises it very nearly to the temperature required for mashing, besides impregnating it very sensibly with the essential oil of the hops, in which the flavour resides.

When the liquor is boiled, it is discharged into a number of coolers, or shallow tubs, in which it remains until it becomes sufficiently cool to be submitted to fermentation. It is necessary that the process of cooling should be carried on as expeditiously as possible, particularly in hot weather; and for this reason, the coolers in the brewhouses are very shallow. Liquor made from pale malt, and which is intended for immediate drinking, need not be cooled lower than 75 or 80 degrees; of course this kind of beer may be brewed in the hottest weather; but beer brewed from brown malt, and intended to be kept, must be cooled to 65° or 70° before it is put into a state of fermentation. Hence in the spring, the month of March, and in autumn, the month of October, have been deemed the most favourable for the manufacture of the best malt liquor.

From the coolers the wort is put into the *working tun*, in which it is mixed with yeast, in the proportion of a gallon to four barrels of wort, in order to excite the vinous fermentation. This process is called *tunning*. By this the beer obtains its strength and spirit; the sugar extracted from the malt being converted into alkohol. In four or five hours the fermentation begins. Its first appearance is by a white line on the surface of the liquor, next to the side of the vessel, which gradually advances to the middle, till the whole surface is covered with a scum, or froth, formed by innumerable minute bubbles of carbonic acid gas, which rise through the liquor. The temperature of the liquor increases, and the whole is much agitated. The froth on the surface accumulates, and constitutes the yeast. At this time the presence of carbonic acid gas may be easily perceived, by holding one's head over the barrel or tun; and fatal accidents have happened through the accumulation of this gas in situations where persons have been exposed to it without being able to remove.

The vinous fermentation must be checked in time, otherwise the acetous fermentation would begin; all the spirit would be lost, and the beer would become sour.

The fermentation requires from 18 or 20 to 48 hours; and the beer is then put into smaller barrels, called *cleansing tuns*. In them, the fermentation goes on again, and during a few days, a copious discharge of yeast takes place from the bung-hole. Care must be taken that the barrels are filled every day with fresh liquor. This discharge gradually becomes less, and in about a week it ceases; when the bung-hole is closed.

The liquor is now suffered to stand for some time to *fine* (or become transparent), by depositing the mucilage that was suspended in it. When there is time, the beer is allowed to fine itself; if not, a preparation of isinglass and sour beer, called *finings*, is put into it, to precipitate the mucilage.

A larger quantity of hops are used in *porter* than for ales. Although in porter the brown malts are necessary, it is bad economy to use them too highly dried for the deepening of the colour, since the consequence of drying too highly is a carbonization of part of the saccharine matter. A dark colour may be procured more economically by adding burnt sugar to the wort.

It is in Britain prohibited by law to use any substance in brewing, as a substitute for hops.

BLEACHING.

Bleaching is the art of whitening cloths, made from vegetable or animal substances, by depriving them of their colouring matter. The art is of great antiquity; and mankind, in all ages, appear to have admired garments of a pure whiteness. The effects produced by the air and rain upon vegetable fibres exposed to them, must have led originally to the idea of producing this by artificial means. The ancients appear to have been acquainted with the uses of soap and leys; and to have practised bleaching, nearly in the same manner as it existed among us until lately. But few manufactures have received so much benefit from modern chemistry, as that now under consideration; so that since the year 1786, it has undergone a complete change.

Bleaching of Linen.

The processes of bleaching differ materially, according to the different materials of which cloths are composed: thus, linen, cotton, woollens, and silk, are whitened by different methods. In order to understand the rationale of the bleaching processes, it is necessary to be acquainted with the nature of the materials.

Flax, from which linen is formed, is a vegetable consisting of several coats or layers. The external coat is a very thin bark; under this is a green juice or sap; next lies a layer of fibres or filaments, which constitutes the part used for making linen; and, lastly, in the centre, there is a woody part. To prepare flax for making cloth, the filaments or fibrous part must be separated from the rest. The filaments are held together by the sap, or succulent part. To detach them from this, the flax is steeped for several days in pools or ponds of soft stagnant water; by which the putrefactive fermentation takes place. But this fermentation must not be suffered to proceed too far; otherwise the fibres themselves would be affected by it, and their texture injured. The flax must be taken out while it is yet green, and while the wood breaks easily between the fingers. The putrefaction of the sap occasions the water in which the flax is steeped to be extremely offensive; and it is even found that the fish are destroyed in any stream where this process is used.

In some places, instead of steeping the flax in water, it is simply exposed to the dew by laying it on the grass.

The time required for this part of the process is variable; depending upon the state of ripeness of the flax, the quality and temperature of the water, and other circumstances.

After steeping the flax, where the watering system is practised, it is spread very thin on the grass, and occasionally turned, until it is found to be very brittle; so that on being rubbed between the hands, the woody part easily separates. It is then dried by the heat of the sun or of a kiln.

The flax is now ready to be *beat* or *broke* by a mill for the purpose, or by mallets on a sort of wooden anvil. The fibres of the flax are thus separated from the wood, which is reduced to fragments, most of which are cleared away by *scutching*.

To divide completely the fibres from each other, and to separate the remaining part of the wood, the process of *hackling* is employed. This consists in drawing the flax through piles or groups of sharp and polished iron spikes, placed close together, and fixed in wood. The hackles are of various degrees of fineness; that is, the spikes are placed at different degrees of distance from each other. The coarsest, or most open hackles, are used first; then a finer, and so on, till the process is completed.

The flax is now ready to be *spun* into thread or yarn, which is manufactured into cloth by the weaver.

The linen, as it comes from the loom, is of a brownish grey colour; and it is then that the process of *bleaching* begins.

The linen is first steeped in *cold* water for 48 hours, to discharge from it the weaver's dressing; which is a paste of flour and water, that had been brushed into the yarn to enable them to stretch it more easily.

The grey substance that colours the linen before it is bleached is of a resinous nature, and consequently it is insoluble in water. It is also intimately united with the fibres of the flax, and is of difficult separation. What appears to the eye to be a single fibre is, in fact, a bundle of minute filaments, agglutinated together by this resinous matter. To separate these filaments from each other, and to destroy entirely the resinous colouring matter, is a process of some difficulty. Solutions of alcalies rendered caustic *, called *alcaline leys*, have the property of dissolving resins; hence they have been used for this purpose in bleaching. The linen is boiled in water containing a quantity of caustic potash, which acts upon the resin of the external filaments, and loosens them a little from each other. The cloth is then spread upon the grass, and exposed to the action of the air, sun, and dew; and is also occasionally watered. It is then returned again into the bucking vat; and the alkaline solution is poured over it: by this another layer of the filaments is opened, and the resin dissolved. It is then carried again to the field, and treated as before. In this manner, the bucking and spreading on the grass are repeated alternately, for 15 or 16 times, according to the weather and other circumstances, until the cloth is whitened. Were the alcaline ley so strong as to dissolve all the resin at once, it would injure the texture of the fabric.

This alternate bucking and exposing on the grass is the old manner of bleaching, and was universally used, till Scheele discovered the properties of the oxygenated muriatic acid in destroying vegetable colours. M. Berthollet first applied this property to the purposes of bleaching, and he, with great liberality, communicated his observations to the public. For this purpose, he immersed the cloth into diluted oxygenated muriatic acid, between the operations of the alcaline leys, which produced the same effect in whitening it, as by exposing it to the action of the air and light in the field.

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* Common potash is rendered sufficiently caustic for the purpose of bleaching, by adding to it quicklime, which has a stronger affinity for the carbonic acid than potash.

The new method of bleaching was quickly and successfully introduced into the manufactories of France; and almost as soon into those of Great Britain. It is now universally adopted. The advantages are, that the time required for bleaching is shortened in a surprising degree so that manufacturers experience a much quicker return of their capitals; and that it may be carried on at all seasons of the year.

The first way in which the oxymuriatic acid was applied in bleaching was in the liquid state; that is, when water is impregnated with the gas. The goods were immersed in this liquid according to the nature of the objects to be bleached. Skeins of thread were suspended on frames in the tub intended to receive them; cloth was rolled upon reels. When every thing was thus disposed, the tubs were filled with oxygenated muriatic acid, by introducing a funnel that descended to the bottom of the tub in order to prevent the dispersion of the gas. The cloth, or thread, was made to pass through the liquid by turning the frames, until it was judged that the acid was exhausted by acting on the colouring matter.

But the volatility of this acid, and the suffocating nature of its vapours, which produced extremely noxious effects upon the health of the workmen, rendered its use very difficult, although very ingenious apparatus had been invented both by Berthollet and by Mr. Watts. It was also found difficult to cause the acid to act upon all parts of the cloths equally, when they were stratified in the cisterns with the acid.

A considerable improvement was made in the apparatus by Mr. Rupp of Manchester, which is described in the Manchester Memoirs. Still it was found that the acid alone was apt to weaken the cloth, and that it injured the health of the workmen.

At length it was discovered by some manufacturers at Javelle, near Paris, that the addition of an alkali to the liquor deprived it of its suffocating effects, without destroying its bleaching powers. Potash was the alcali they employed; and this solution was called the Javelle liquor. The inventors came into this country, and established a bleaching-work. The process was then carried on in open vessels; and the bleacher was able to work his pieces in the liquid, and expose every part to its action without inconvenience.

Although these advantages were unquestionably great, they were diminished by the heavy expense of the alcali, which was entirely lost. Also, the the potash, which added to the liquor, though it did not destroy its power of bleaching, diminished it; because a solution of the oxygenated muriate of potash, which differs from this bleaching-liquor in nothing but in the proportion of alcali, will not bleach at all. This is a well-known fact; from which we might infer, that the oxygenated muriatic acid will lose its power of destroying the colouring-matter of vegetable substances, in proportion as it becomes neutralized.

Mr. Tennant discovered that lime might be substituted for the potash, the oxymuriatic acid combining with all the alcaline earths, and forming oxymuriates which were soluble in water, and had the property of bleaching. This is the substance now employed. If the oxygenated muriatic acid be passed through lime-water, it will combine with the lime, and form oxymuriate of lime; but as the water can only retain a small portion of lime, this was not found of much use. To cause a larger quantity of lime to combine with the oxymuriatic acid gas, the lime is mechanically suspended by agitation in the water into which the gas is made to pass, so as to present fresh matter to the gas. By this means, the oxymuriatic acid combines with the lime, forming a compound soluble in the water: this is used as a bleaching-liquor.

The oxygenated muriatic acid gas may also be combined with lime in a dry state. To effect this, the oxymuriatic acid gas is sent into a vessel containing dry hydrate of lime (that is, lime slacked with water): the powder is agitated, and the gas combines with it to a certain amount, or till the hydrate of lime becomes saturated. The compound is a soft white powder, possessing little smell. It is partially soluble in water, yielding a solution much the same as that obtained by the former process.

Although most salts that are soluble in water are capable of being formed again by evaporating the water, either in crystals or in a dry saline mass, this is not the case with oxymuriate of lime. Whenever a solution of it is evaporated, part of the acid escapes, and the rest is mostly converted into muriatic acid; so that instead of *oxymuriate* of lime, *muriate* of lime is obtained. Hence the dry salt cannot be obtained from the liquid solution.

The dry oxymuriate of lime may be very conveniently transported without injury, an advantage not possessed by the acid alone, which cannot be transported without the loss of almost half its strength: but it must be observed that the dry salt is much impaired by being long kept.

We have hitherto used the old term of oxymuriatic acid, because it is best known by this name in the bleaching processes; but it will be remembered that this substance is now considered as a simple body, and is known by the name of chlorine. What has just been called oxymuriate of lime is known among modern chemists by the term chlorate of lime.

The oxymuriatic acid gas, or chlorine, may be procured by distilling muriatic acid in black oxide of manganese; but to save the expense of first preparing the muriatic acid, the usual practice in bleaching is to mix three parts of black oxide of manganese with eight parts of muriate of soda or common salt, and five parts sulphuric acid, diluted with four parts water.

To ascertain the strength of the liquid for bleaching, a solution of indigo in the sulphuric acid is employed. The colour of this is destroyed by the oxygenated muriatic acid; and according to the quantity of it that can be discoloured by a given quantity of the liquor, its strength is known.

The linen is usually not immersed in the solution of oxymuriate of lime until after the fourth or fifth bucking; because a great portion of the resin is removed cheaper by the alkaline leys, and washing in water.

The last operation in bleaching is *souring*, or steeping the linen in some sour liquid of a blood heat. For this purpose, formerly sour milk was employed: but now sulphuric acid is used. Of this as much is put into water as will give it the acidity of vinegar. The linens are generally steeped about twelve hours, and are then well washed. This souring is essential to the procuring of a good white, but the theory of its action is not well understood.

Nothing now remains, in order to complete them for the market, but rubbing them with a strong lather of soap, washing, and blueing them.

The alcali is one of the chief articles of expense used in bleaching: and it is a great object with the bleacher to recover the pure alcali from the leys which have been used.

The sulphuret of lime, or the combination of sulphur and lime, which are both cheap articles, has been used in Ireland for bleaching, instead of potash. It was first proposed by Mr. Higgins, and it answers in some cases, particularly where the goods are intended for dying.

The sulphuret of lime is prepared as follows:—sulphur in powder, four pounds; lime, well slaked, twenty pounds; and water, sixteen gallons; are to be well mixed, and boiled for half an hour in an iron vessel, stirring them briskly from time to time. Soon after the agitation of boiling is over, the solution of the sulphuret clears, and may be drawn off free from the insoluble matter, which is considerable, and which rests upon the bottom of the boiler. The liquor in this state is pretty nearly of the colour of small beer, but not quite so transparent.

Sixteen gallons of fresh water are afterwards to be poured upon the insoluble dregs in the boiler, in order to separate the whole of the sulphuret from them. When this clears (being previously well agitated) it is also to be drawn off and mixed with the first liquor; to these again, thirty-three gallons more of water may be added, which will reduce the liquor to a proper standard for steeping the cloth. Here we have (an allowance being made for evaporation, and for the quantity retained in the dregs) sixty gallons of liquor from four pounds of sulphur.

Although sulphur, by itself, is not in any sensible degree soluble in water, and lime but sparingly so, water dissolving only about one seven hundredth part of its weight of lime; yet the sulphuret of lime is highly soluble.

After the paste used by the weaver has been removed, the linen is steeped in a solution of the sulphuret of lime, prepared as above, for about twelve or eighteen hours. It is then washed, and steeped in oxymuriate of lime. This process is repeated by six alternate immersions in each liquor.

For the use of private families, where the linen is dirtied by perspiration or grease, it will be of great service towards rendering it white, to steep it for some time in a clear liquor, made by mixing one quart of quick-lime in ten gallons of water, letting the mixture stand for twenty-four hours, and then using the clean water drawn off from the lime. After the linen has been steeped in this liquor, it should be well washed as usual, but will require much less soap to be used.

It is of great consequence in bleaching with the oxygenated muriatic acid, that it may be employed of a proper strength; as a test to ascertain its strength, a solution of indigo in sulphuric acid is used. A certain quantity is put into a glass tube, and oxygenated muriatic acid is added until the colour of the indigo is destroyed: by the quantity of acid necessary to destroy the colour, its strength is estimated.

Steam has been employed in bleaching in France with great success. The process was brought from the Levant. Chaptal first made it known to the public. When an alcaline ley is boiled, a certain quantity of alcali always rises with the steam. The cloth is first immersed in weak caustic alcaline liquor, and placed over a chamber constructed over a boiler, into which is put the alcaline ley which is to be raised into steam. After the fire has been lighted, and the cloth has remained exposed to the action of the steam for a sufficient length of time, it is taken out, and immersed in the oxygenated muriate of lime, and afterwards exposed for two or three days on the grass.

This operation, which is very expeditious, is sufficient for cotton; but if linen-cloth should still retain a yellow tint, a second alcaline vapour-bath, and two or three days exposure on the grass, will be sufficient to give them the necessary degree of whiteness.

Bleaching of Cotton.

Cotton is a vegetable substance, and the production of a shrub that grows only in warm climates. It is a fine downy substance, in which the seeds of the plant are inclosed. Cotton, in its natural state, is generally of a dirty yellow, and opaque, being covered with a colouring matter of an unctuous nature; when this is removed, it is white and transparent.

Cotton is easier to bleach than linen. The colouring-matter is dissolved by the action of alcaline leys and washing. Sometimes the oxymuriatic acid is also used to expedite the process. Steeping in diluted sulphuric acid, is also used to dissolve the earthy matter that always remains after the immersion in alcaline ley; and as cotton is not so easily injured by acids as flax, more use is made of the acid than in the bleaching of linen. The action of steam is very efficacious in bleaching cottons.

In bleaching cotton for calico-printing, a pure white is not so much sought for, as that the oil may be entirely extracted.

In applying the alcaline ley, great care must be taken that no lime remains in suspension in the liquor, as it might be fixed in the cloths; and when the sulphuric acid is used, a sulphate of lime would be formed, which in fact is a mordant for the madder; hence the latter could not be discharged from those parts intended to be white.

For the same reason, the oxymuriate of lime cannot be used, if madder is to be discharged from any part of the cloth. When this is the case, oxymuriate of potash, or of soda, is substituted for oxymuriate of lime.

Bleaching of Wool.

The bleaching of animal substances is somewhat different from the processes employed for vegetable substances.

Wool is a sort of very fine hair which covers the bodies of some animals. Each hair is hollow, and contains an oily matter.

Wool is not easily acted upon by acids; is unalterable by water, cold or boiling; but may be entirely dissolved by strong alcaline leys. On this account, the latter must be used with great caution.

Wool is oiled before it is combed and spun, and the first operation is to free it from the oil which it has thus acquired. This is called *scouring*. Stale urine, which contains ammonia or the volatile alcali, is mixed with water; and the wool is immersed in this for about twenty minutes, heated to 56° Fahr. It is then taken out, drained, and rinsed in running water; then put into the bath of urine, and washed again. This is sometimes repeated a third time, and sometimes scouring with soap is used.

Fulling the cloth adds also to its whiteness. Fulling is a species of scouring with a particular kind of earth called *fuller's earth.* It effectually removes all grease, from the chemical affinity existing between the alumina contained in the fuller's earth and the oil of the cloth; and thus disposes the fibres to be entangled and matted together in the subsequent process of *milling*, employed to thicken the cloth, and render it stronger and firmer.

Scouring entirely with soap is preferred when the articles are valuable.

Sulphureous acid is also used for giving the last degree of whiteness.

Sulphuring is performed in the following manner. The articles to be whitened are suspended uopn poles across a chamber, constructed so as to be perfectly close. Into this chamber is previously put a quantity of sulphur in dishes. When the cloth is in, the sulphur is set fire to, and the doors of the chamber are accurately shut, and all the interstices carefully stopt up, so as to exclude entirely the atmospheric air.

The combustion of the sulphur produces a vapour which is the sulphureous acid; this destroys the colouring matter of the wool, which is consequently rendered white. The time necessary for this process varies from six to twenty-four hours. The cloth is left in the chamber for some time after the combustion of the sulphur has ceased; it is then taken out and rinsed, to remove the acid; and afterwards washed with soap, to give a degree of softness.

This mode of bleaching by the combustion of sulphur is also used for other substances, as straw in the manufacture of hats, &c.

A superior method of employing the sulphureous acid in bleaching is the following. Water is impregnated with the sulphureous acid, and tubs are filled with this; then the stuffs are drawn through it upon reels, till they are whitened. The sulphureous acid is made by decomposing the sulphuric acid by the addition of any combustible matter capable of taking away a part of its oxygen. A cheap method of effecting this is by putting chopped straw, or saw-dust, into a mattrass, and then pouring over it sulphuric acid, and afterwards applying heat. The sulphureous acid gas will be formed, but will be combined with the water in the vessel. The stuffs are then taken out, and left to drain upon a bench covered with cloth; a precaution which is necessary, because the wood might be decomposed by the sulphuric acid, and would stain the goods. They are afterwards washed in clear water. It is generally necessary to sulphur them twice before the white is sufficiently bright. Sometimes Spanish white is put into the water used for washing them; and they are also *azured* or *blued* by disolving some Prussian blue in the water. Nothing then remains to be done but *drying*, *stretching*, and *pressing*.

Bleaching of Silk.

Silk is an animal substance, and is prepared by a caterpillar, usually called the silk-worm. This insect inhabits warm climates, and cannot be reared in this country without difficulty, nor in sufficient quantity for the purpose of procuring silk. The south of Europe and Asia are its proper countries.

The silk is spun by the silk-worm in the form of threads of a semi-transparent matter, which it winds up round itself when it passes into the crysalis state. The threads, when formed, are connected together by a viscous substance, from which they must be separated before they can be wound off, by putting them into hot water.

The silk itself is covered with a yellow varnish, which is soluble in alcaline leys; and as this varnish conceals the lustre of the silk, it is necessary to detach it. Silk is itself soluble in strong alkaline leys; care must be taken, therefore, not to injure the silk in taking off the varnish. Water at a boiling heat has no action on silk; but steam dissolves its varnish.

In France they proceed as follows. They fill a boiler with a very weak solution of caustic soda, and place in a chamber connected with the boiler, the skeins of raw silk, wound on frames; then they close the door of the chamber, and make the solution in the boiler boil. Having continued the ebullition for twelve hours, they slacken the fire, and open the door of the chamber. The steam, which is always above 250° Fahr., will have dissolved the gum of the silk. The skeins are then washed in warm water, wrung, and boiled a second time; then washed again several times with soap, till they have acquired the necessary whiteness and softness.

It is not possible, however, to give to silk all the necessary splendour by this process alone; to complete it, the silk must be exposed to the action of the sulphureous acid, either in the form of gas, or combined with water, as directed for wool.

Bleaching Prints and Printed Books.

An application has been made of the new mode of bleaching to the whitening of books and prints that have been soiled by smoke and time.

Simple immersion in oxygenated muriatic acid, letting the article remain in it a longer or shorter space of time, according to the strength of the liquid will be sufficient to whiten an engraving.

If it be required to whiten the paper of a bound book, as it is necessary that all the leaves should be moistened by the acid, care must be taken to open the book well, and to make the boards rest upon the edge of the vessel in such a manner that the paper alone be dipped in the liquid: the leaves must be separated from each other, so that they may be equally moistened on both sides.

The liquor assumes a yellow tint, and the paper becomes white in the same proportion; at the end of two or three hours the book may be taken from the acid liquor and plunged into pure water, with the same care and precaution as recommended in regard to the acid liquor, that the water may exactly touch the two surfaces of each leaf. The water must be renewed every hour, to extract the acid remaining in the paper, and to dissipate the disagreeable smell.

By following this process, there is some danger that the pages will not be all equally whitened, either because the leaves have not been sufficiently separated, or because the liquid has had more action on the front margins than on those near the binding. On this account, the best way is to destroy the binding entirely, that each leaf may receive an equal and perfect immersion; and this is the second process recommended by M. Chaptal.

"They begin," says he, "by unsewing the book, and separating it into leaves, which they place in cases formed in a leaden tub, with very thin slips of wood or glass; so that the leaves, when laid flat, are separated from each other by intervals scarcely sensible. The acid is then poured in, making it fall on the sides of the tub, in order that the leaves may not be deranged by its motion. When the workman judges, by the whiteness of the paper, that is has been sufficiently acted upon by the acid, it is drawn off by a cock at the bottom of the tub; and its place is supplied by clear fresh water, which weakens and carries off the remains of the acid, as well as the strong smell. The leaves are then to be dried, and, after being pressed, may be again bound up.

"The leaves may be placed also vertically in the tub; and this position seems to possess some advantage, as they will be less liable to be torn.

"With this view, I constructed a wooden frame, which I adjusted to the proper height, according to the size of the leaves I wished to whiten.

"This frame supported very thin slips of wood, leaving only the space of half a line between them. I placed two leaves in each of these intervals, and kept them fixed in their place by two small wooden wedges which I pushed in between the slips.

"When the paper was whitened, I lifted up the frame with leaves, and plunged them in cold water, to remove the remains of the acid as well as the smell; this process I prefer to the other.

" By this operation, books are not only cleaned, but the paper acquires a degree of whiteness superior to what is possessed when first made.

" The use of this acid is attended also with the valuable advantage of destroying ink-spots. This liquor has no action upon spots of oil or animal grease; but it has been long known that a weak solution of potash will effectually remove stains of that kind.

" When I had to repair prints so torn that they exhibited only scraps pasted upon other paper, I was afraid of losing these fragments in the liquid, because the paste became dissolved. In such cases, I enclosed the prints in a cylindric glass vessel, which I inverted on the water in which I had put the mixture proper for extricating the oxygenated muriatic acid gas. This vapour, by filling the whole inside of the jar, acted upon the print, extracted the grease as well as ink-spots, and the fragments remained pasted to the paper."

Bleaching of Paper.

The oxygenated muriatic acid has also been applied to the bleaching of paper, which it has rendered considerably more expeditious.

Bleaching of old printed papers to be worked up again.—Boil the paper for an instant in a solution of soda, rendered caustic by potash. Steep it in soap water, and then wash it, after which the paper may be reduced to a pulp by the paper-mill.

Bleaching of old written papers to be worked again.—Steep the papers in a cold solution of sulphuric acid in water, after which wash them before they are taken to the mill. If the acidulated water be heated, it will be the more effectual.

Bleaching of printed papers without destroying the texture of the leaves.—Steep the leaves in a caustic solution of soda, and afterwards in one of soap. Arrange the sheets alternately between cloths in the same manner as paper-makers dispose their sheets of paper when delivered from the form. Put the leaves in a press, and they will become whiter, unless they were originally loaded with printers' ink or size. If this should not completely effect the whitening of the leaves, repeat the process a second, or even a third time.

Bleaching coloured rags to make white paper. — Soak or macerate the rags sufficiently; put them into a solution of caustic alcali, and then into the oxygenated muriatic acid; and, lastly, steep them into diluted sulphuric acid.

DYEING.

Dyeing is the art of extracting the colouring principle from different substances, and transferring them to wool, silk, cotton, or linen. When other matters are coloured, the process is called *staining*.

In dyeing, the colouring matter is not merely deposited on the stuff, but is firmly attached to it by chemical combination depending on an *affinity* subsisting between them.

If the colouring matters were merely spread over the surface of the fibres of the cloth, the colours produced might be very bright, but they would not be permanent, since they would be rubbed off, and would disappear when the cloth was washed, or even by exposure to the weather. Dyeing is, therefore, a chemical process, consisting in combining a certain colouring matter with fibres of cloth. The colouring matters are, for the most part, extracted from animal and vegetable substances, and have usually the colour which they give to the cloth.

The particles of these colouring matters appear to be transparent, because the original colour of the cloth will appear through them. The colour of dyed cloth, therefore, does not depend upon the dye alone, but also upon the previous colour of the cloth. Thus, if the cloth be *black* it will not receive a dye of any colour; and hence it is necessary, that the cloth should be white, if we wish to dye it of a very bright colour.

The colouring matter, or dye-stuff, must be dissolved in some liquid, that the particles may be precipitated upon the cloth; and it is essential that its affinity for this solvent should not be so strong as for the cloth to be dyed.

Thus the facility with which cloth imbibes a dye depends upon two things; namely, the affinity between the cloth and the dye stuff, and that between the dye stuff and its solvent. Much of the accuracy of dyeing depends upon preserving a due proportion between these two affinities. If the affinity between the dye-stuff and cloth, compared with that between the dye-stuff and the solvent be too great, the cloth will receive the dye too quickly, and the colour will be apt to be unequal: and if the affinity between the dye-stuff and the solvent be greater than between the dye-stuff and the cloth, the latter will scarcely receive the dye, or, at least, very faintly.

Wool has the strongest affinity for colouring-matters; silk the next strongest; cotton has much less affinity; and linen has the least of all. Hence the dye-stuff for cotton or linen should be dissolved in substances which they have less affinity for, than when silk or wool are to be dyed. Thus iron dissolved in the sulphuric acid may dye wool; but when it is intended to dye cotton and linen by iron, the latter should be dissolved in the acetous acid.

There are few colouring substances that have, of themselves, so strong an affinity for cloth as to answer the purpose of dyeing so as to remain permanent; and, on this account, an intermediate substance is employed, that has a decided attraction for both the colouring matter and the cloth, thus serving as a bond of union between them. This substance is previously combined with the cloth, which is then dipped into the solution containing the dye-stuff. The dye-stuff combines with the intermediate substance, which being firmly combined with the cloth, secures the permanence of the dye. Substances employed for this purpose are denominated *mordants*. Instead of this some prefer the term *basis*.

The most important part of dyeing consists in the proper choice, and the proper application of mordants; as upon them, the permanency of every dye depends. What has been said respecting the application of colouring matters applies equally to the application of mordants. They must be previously dissolved in some liquid, which has a weaker affinity to them than the cloth has, to which they are to be applied; and the cloth must be dipped, or even steeped in this solution, in order to saturate itself with the mordant. The mordants are earths, metallic oxides, tan, and oil.

Of the earths, alumine is the most useful. It is applied in the state of sulphate of alumine, or common alum; and in that of acetate of alumine.

When alum is used as a mordant, it is dissolved in water, and sometimes a quantity of tartar is added. The cloth is put into this solution, and kept till it has absorbed as much alumine as is necessary. It is then taken out, and is washed and dried. A quantity of alumine has by this process combined with the fibres of the cloth, which is perceived by the latter weighing more than before. The addition of the tartar, or tartrate of potash, is made on two accounts; the potash which it contains combines with the sulphuric acid of the alum, and thus prevents that very corrosive substance from injuring the texture of the cloth: the tartareous acid, on the other hand, combines with part of the alumine, and forms a tartrate of alumine, which is more easily decomposed by the cloth than alum.

Acetate of alumine is used as a mordant for cotton and linen, which have a much less affinity than wool for alumine. The alumine is retained less powerfully in a state of combination by the acetic than by the sulphuric acid; and, therefore, cotton and linen are better able to separate it and attach it: also the acetic acid being volatile, gradually leaves the earthy basis, and allows the alumine to unite to the stuff.

This mordant is now prepared by pouring acetate of lead into a solution of alum; on which a double decomposition takes place; the sulphuric acid combines with the lead, and the sulphate of lead precipitates in the form of an insoluble powder, while the alumine combines with acetous acid, and remains in the liquor.

This mordant gives a richer colour than alum.

Lime is also sometimes employed as a mordant: but it does not answer so well in general, not giving so good a colour. It is used either in the state of lime water, or as sulphate of lime dissolved in water.

Although all the metallic oxides have an affinity for cloth, only two, the oxides of tin and of iron, are much used as mordants.

The oxide of tin is one of the most valuable mordants, and is the only one by which scarlet, the brightest of all colours, can be produced. It was first brought to London by Karsten, a German, in 1543, which period forms an epoch in the history of dyeing.

Proust has shown that tin has two oxides. The first, or grey oxide, consists of seventy parts of tin, and thirty oxygen: the second, or white oxide, of sixty parts of tin, and forty oxygen. The first oxide absorbs oxygen rapidly from the air, and becomes converted into the white oxide. It is, therefore, the white oxide alone that is the real mordant; since if the first were applied to cloth, as it probably often is, it must soon be converted into the white oxide by absorbing oxygen.

Tin is used as a mordant in three states; dissolved in nitro-muriatic acid, in acetous acid, and in a mixture of sulphuric and muriatic acids. That commonly used by the dyers, and called by them *spirit of tin,* is the nitro-muriate. It is prepared by dissolving granulated tin in very dilute nitric acid, or what is called single aquafortis: and a quantity of muriate of soda, or muriate of ammonia, is added. These salts are decomposed by the nitric acid, and the muriatic acid is set free. sometimes to economize the nitric acid, a quantity of sulphuric acid is added, just sufficient to saturate the base of the muriate of soda.

When nitro-muriate of tin is used as a mordant, it is dissolved in a large quantity of water, and tartar is added. The cloth is then put in and kept till it is saturated. A double decomposition takes place; the nitro-muriatic acid combines with the potash of the tartar, while the tartareous acid dissolves the oxide of tin. When tartar is used, therefore, in any considerable quantity, the mordant is not a nitro-muriate, but a tartrate of tin.

The *murio-sulphate of tin*, produced by dissolving tin in muriatic acid, combined with about one-fourth of its weight of oil of vitriol, is also a valuable mordant, and is preferable to the last for some purposes; it is also less expensive.

The oxide of iron is also a very useful mordant, and all kinds of cloth have a strong affinity for it. The permanency of the iron spots on linen and cotton is a sufficient proof of this. Iron, as a mordant, is used in different states. Wool is dyed generally by means of the sulphate of iron, which may also be used for cotton. Acetate of iron, prepared by dissolving iron in vinegar, sour beer, &c., is preferable for some purposes. The pyro-ligneous acid, which differs from the acetic only in having in combination a certain quantity of empyreumatic oil, is at present preferred to the sulphuric, or acetic.

The astringent principle, or *tannin*, is also employed as a mordant, and has a strong affinity for cloth, and also for colouring matters. An infusion of *nut-galls*, *sumach*, *oak bark*, or any other substance containing tannin, is made in water, and the cloth is kept in it till it has absorbed a sufficient quantity of *tannin*. Silk has so strong an affinity for tannin, that manufacturers sometimes employ this circumstance to increase the weight of their silk.

A compound mordant is sometimes produced by impregnating the cloth first with oil, then with the astringent principle, and, lastly, with the aluminous mordant. This is employed in dyeing the Adrianople red.

Several other substances are used as mordants occasionally, either as principals, or to facilitate the combinations of others with the cloths; such as nitrate of bismuth, oxide of arsenic, corrosive sublimate, acetate of lead, sulphate, or acetate of copper, &c.

The chief use of mordants is to render the dyes permanent, but they have also considerable influence on the colour produced: thus, the same colouring matter will produce very different dyes, according to the mordant used to fix it. If the aluminous mordant be used for cochineal, the colour will be crimson; but if the oxide of iron be used for the same colouring matter, black will be the result.

It is necessary, therefore, to choose such mordants and colouring matters as together shall produce the desired colour. And this principle enables us also to produce various colours with the same dye-stuff, only by changing the mordant.

It is probable that the whole of the surface of the fibres of cloth are not covered by the colouring matters precipitated upon them; but that the particles of colour are at some distance from each other. For cloth may be dyed different shades of the same colour; that is, it may be dyed deeper a second time than at first, by increasing the quantity of colouring matter, which could not be the case if the whole surface were covered. Another circumstance renders this opinion probable; all those colours which dyers call *compound* are made by dyeing the cloth first one colour, and then another: thus, green is got by dyeing cloth first blue and then yellow.

In dyeing, the water employed should be as pure as possible, and the exact temperature in each process should be attended to. The dye-houses should be spacious, light, and airy, and cleanness is essentially necessary. The stuffs are supported in the cauldrons, or baths, by proper apparatus, and are drawn through them by a winch, or reel.

Of Dyeing Red.

The colouring matters employed for dyeing red are cochineal, kermes, madder, lac, Brazil-wood, logwood, and carthamus. *Cochineal* is a species of insect (the *coccus cacti*, Lin.) brought from America. The decoction of it affords a very bright crimson colour, inclining to violet. When alum is added to this decoction, it combines with its colouring matter, and forms a red precipitate. Muriate of tin gives a still more beautiful colour.

Kermes is also an insect found in several parts of Asia, and the south of Europe, which furnishes a red dye, by some thought not inferior to cochineal, but which has not been so much used since the introduction of the latter.

Madder is the root of a plant (*rubia tinctorium*, Lin.) The colouring matter of madder is extracted by water, either cold or hot, and precipitates of various shades of red may be obtained by alum, chalk, acetate of lead, and muriate of tin.

Lac is a colouring matter of animal origin, produced in the East Indies, from the *coccus lacca*, a small winged insect. This insect forms cells for its young, as regular as the honey-comb, but differently arranged; and the lac is procured from the substance of which these cells are made. The whole matter of these cells is called *stick lac;* when the red colouring matter is extracted by water, what remains is a resinous substance called *shell lac*, used for various purposes, as varnishes, sealing wax, &c. Water dissolves lac, and the decoction is of a deep crimson colour. The precipitate, with alum or nitro-muriate of tin, forms a fine red.

Brazil-wood is an article used in dyeing. It is the central part of a large tree, that grows in Brazil. It is heavier than water, and affords a decoction of a red colour with water. The precipitate, with alum and nitro-muriate of tin, is a fine red.

Peach-wood gives a colour inferior to Brazil, and also in smaller quantity.

Logwood affords a colouring matter extensively used in dyeing. It is very heavy, and sinks in water. Its decoction is yellow, but by alum becomes violet or purple; by sulphate of iron it becomes black.

Carthamus is the flower of a plant cultivated in Spain and the Levant. It contains two colouring matters; a yellow, which is soluble in water; and a red, which is insoluble in water, but soluble in alcaline carbonats. The red colouring matter of carthamus, extracted by carbonate of soda, precipitated by lemon-juice, and ground with talc, constitutes the *rouge* employed as a cosmetic: the fineness of the talc, and the proportion of it mixed with the carthamus, occasion the difference between the cheaper and dearer kinds of rouge.

Wool is died scarlet, which is the most splendid of all reds, by cochineal. Alum will do as a mordant for fixing the red; but nitro-muriate of tin, or what is still better, the murio-sulphate of tin, are now used as preferable mordants. To die wool scarlet, a bath is made by mixing pure tartar with a little cochineal and nitro-muriate of tin; but as the red produced by cochineal alone is rather a crimson than a scarlet; and as the colour of scarlet is, in fact, crimson and yellow, some yellow dye, or fustic, turmeric, or quercitron bark, is added to the cochineal in the first bath.

Into this the cloth is put, and boiled for two hours. It is then washed, and afterwards put into a second bath of cochineal, which is called the reddening. When crimson is the colour to be given to the cloth, the tin mordant is the best; but sometimes the dyers use the alum for this purpose, and then a decoction of cochineal. The addition of archil and potash renders the crimson darker, and gives it more bloom, but this is very fugitive. For paler crimsons, some madder is substituted for a portion of the cochineal. Wool is dyed madder-red, by boiling it first two or three hours with alum and tartar, and then in a bath of madder.

Silk may be dyed crimson with cochineal or Brazil-wood, and sometimes carthamus is used. The nitro-muriate of tin is the best mordant, but alum may be also used. Madder does not give a colour sufficiently bright.

Poppy colour, cherry, rose, and flesh colour, are given to silk by carthamus or Brazil-wood. When the carthamus is employed, an alcaline solution is made, and as much lemon-juice as will give it a fine cherry-red is poured into it.

It is extremely difficult to give silk a scarlet, and it is scarcely possible to give it a full scarlet. The murio-sulphate of tin, as a mordant, is first used, then the bath of cochineal and quercitron, and lastly, the cochineal bath alone. A colour approaching to scarlet may also be given to silk, by dyeing it first crimson, then dyeing it with carthamus, and lastly yellow, without heat.

Cotton and linen are dyed red with madder. Cochineal, which gives so fine a red to wool, by the nitro-muriate of tin, communicates only a dirty red to cotton and linen, by the same means.

Madder reds are of two kinds. 1. The common madder red, which is formed by impregnating the cotton or linen with galls, and afterwards alumed, and then putting them into the madder bath. 2. The Adrianople, or Turkey red. This process was brought from the East. It is more durable and more beautiful than the common red. The cloth is first impregnated with oil, then with galls, and lastly, with alum. It is then boiled for an hour, in a decoction of madder, which is commonly mixed with a quantity of blood. After the cloth is dyed, it is plunged into a soda ley, in order to brighten the colour. The chief difficulty is in the application of the mordant, which is the most complicated employed in the whole art of dyeing.

Cotton may be dyed scarlet by the murio-sulphate of tin, cochineal, and quercitron bark; but the colour is extremely fugitive.

Of Dyeing Yellow.

The chief yellow dyes are weld, sumach, fustic, turmeric, and quercitron bark.

Weld is a vegetable that grows commonly in this country.

Sumach is a shrub growing naturally in the South of Europe.

Fustic is the wood of a tree which grows in the West Indies.

Quercitron is the bark of a tree which is a native of North America.

It is not possible to give to cloth a permanent yellow colour without the use of mordants. Alum is the most usual mordant. *Wool* is dyed yellow by weld, by the use of alum and tartar. Quercitron bark gives nearly the same colour, but more abundantly, and it is rather cheaper than weld. The process is as follows: boil the cloth for an hour or more in a solution of alum, and then immerse it in a bath of quercitron bark. Next add a small quantity of clean powdered chalk, and continue the boiling for eight or ten minutes. The yellow thus given will be as good as that obtained from weld.

If very bright yellows are required, the tin mordant must be used; and sometimes alum is added to the tin.

If an addition of tartar be made to the mordant, the yellow will have a slight tinge of green.

If an orange or an aurora be required, a small portion of cochineal must be added.

Silk used formerly to be always dyed yellow with weld, but quercitron bark is now found to answer equally well, and at less expense. The proportion should be from one to two parts of bark to twelve pounds of silk, according to the particular shade of colour wanted. The bark, powdered and tied up in a bag, should be put into the dyeing vessel whilst the water is cold, and as soon as it becomes blood warm, the silk previously alumed should also be put in and dyed as usual, and when the shade is required to be deep, a little chalk or pearl-ashes may be added towards the end of the operation.

When very lively yellows are required, a little of the murio-sulphate of tin may be employed as a mordant in addition to the alum. Annotto communicates an aurora colour to silk, the colour of the annotto is extracted by means of alcali.

To dye *cotton* and *linen* yellow, proceed as follows. Take a sufficient quantity of the acetate of alumine, formed by dissolving one pound of sugar of lead, and three pounds of alum, and the cotton or linen being properly cleansed, immerse it in this mordant (which ought to be blood warm) for two hours, let it be then taken out and moderately pressed or squeezed over a proper vessel, to prevent the unnecessary waste of the mordant, dry it in a stove heat, and soak it again in the aluminous mordant; it is then taken out, and again pressed and squeezed as before; after which, without being rinsed, it is thoroughly wetted in as much, and only as much, lime-water as will conveniently suffice for that purpose, and afterwards dried. The soaking in the acetate of alumine may be again repeated, and if the shade of yellow is required to be very bright and durable, the alternate wetting with lime water and soaking in the mordant may be repeated three or four times. Thus a sufficient quantity of alumine is combined with the cloth, and the combination is rendered more permanent by the addition of some lime. The dyeing both is prepared by putting 12 or 18 parts of quercitron bark, (according to the depth of the shade required,) tied up in a bag, into a sufficient quantity of cold water. Into this bath the cloth is to be put, and turned round in it for an hour, while its temperature is gradually raised to about 120°, it is then to be brought to a boiling heat, and the cloth allowed to remain in it after that only a few minutes. If it be kept long at a boiling heat, the yellow acquires a shade of brown.

To dye nankeen yellow, boil the cotton in a solution of carbonate of potash, and then dip it in a solution of the red sulphate of iron.

Of Dyeing Blue.

There are but few substances capable of furnishing blue dyes. The only vegetable products are indigo and wood. *Indigo* is a rich blue colour procured from the fecula of a species of plant that is cultivated in America, and also in the East Indies. The colouring matter is extracted by water, and is at first green, but immediately absorbs oxygen, and then assumes a blue colour. It becomes at the same time insoluble in water, but is soluble in sulphuric acid.

As indigo has a very strong affinity for wool, silk, cotton, and linen, a mordant is unnecessary in dyeing with it. The colour is very permanent, because the indigo being already saturated with oxygen, to which it owes its blue colour, is little liable to be decomposed. But it is essential that the indigo be applied in a state of solution in order to attach itself to the cloth.

A solution of indigo in the sulphuric acid is used for dyeing wool; this is called *Saxon blue,* and it gives a very beautiful colour. But it will not do for dying cotton or wool, because their affinity for indigo is not sufficiently great to enable them to decompose the sulphate of indigo.

To dye by the sulphate of indigo, dissolve one part of indigo in four parts of concentrated sulphuric acid; add to the solution one part of dry carbonate of potash, and dilute the whole with eight times its weight of water. Boil the cloth for an hour in a solution of five parts of alum, and three of tartar, for every thirty-two parts of cloth. The cloth is then to be put into a bath of sulphate of indigo, diluted according to the strength of shade required, and kept till it has acquired the desired colour. The use of the alum and tartar is not to act as mordants, but to facilitate the decomposition of the indigo. The alcali is added to the sulphate for the same reason. Another use of these substances is, that they protect the cloth from the action of the sulphuric acid, by neutralizing part of it, otherwise the texture of the cloth might be injured.

This, however, is not the most common method of dyeing by indigo. The usual method is to deprive the indigo of the oxygen which has been combined with the green fecula, and to which it owes its blue colour, and thus reduce to the green state again. It is then capable of being dissolved in water by means of the alcalies or alcaline earths, which act upon it very readily in that state,

To dye *wool* blue, indigo is mixed with wood, bran, and madder, vegetable substances which readily undergo fermentation; and the whole is boiled together, stirring the mixture frequently. By this a fermentation takes place, and the oxygen is separated from the indigo. Quick lime or alcali is then thrown in, which dissolves the green base of the indigo. The solution of indigo is apt to run into the putrid fermentation, which is known by the putrid vapours which it exhales; the green colour then disappears, and, indeed, the colouring matter is decomposed. This danger is prevented by adding more lime to correct the putrescent tendency. Sometimes the fermentation does not proceed with sufficient activity, and then more bran or wood is to be added. When the wool or cloth is to be put into the indigo vat to be dyed, it should be wrung out of tepid water, and then introduced into the vat, where it should be kept for a longer or shorter time according to the strength of shade required. After being taken out, it is exposed to air, when the green colour which it had imbibed in the vat is changed to a blue by the absorption of the oxygen of the atmosphere. It is then to be carefully washed.

Woad itself contains a colouring matter exactly similar to indigo, and indigo may be extracted from it, but the quantity is small.

Cotton and *linen* are dyed blue by putting the indigo into a solution of some substance that has a stronger affinity for oxygen than the green bases of indigo. Green sulphate of iron, and metallic sulphurets answer this purpose, the green sulphate attracts the oxygen from the indigo, and reduces it to the green state, in which it is dissolved by lime added to the solution. The cloth is then put into the bath.

Silk is dyed blue by indigo fermented by bran and madder, and the indigo dissolved by potash. If the shade required be dark, it is dyed first with archill, which is called giving it a *ground* colour.n

Of dyeing Black.

The substance that produces the black dye is the *tanno-gallate* of iron. Decoctions of many vegetables strike a black with a solution of the red oxide of iron. Of these nut-galls give the most copious precipitate.

Logwood is generally employed as an auxiliary, because it communicates lustre, and adds considerably to the fullness of the black. The decoction of logwood which is reddish becomes black by sulphate of iron.

To dye cloth or wool black, the first process generally is to dye it blue, which renders the black to be given more intense. If the cloth be coarse, and the blue dye too expensive, a brown dye may be given by means of walnut peels. It is then boiled for two hours in a decoction of nut galls, and then for two hours more in a bath composed of logwood and sulphate of iron, at a scalding heat, but not boiled. During the operation, it must be frequently exposed to the air. The common proportion are five parts of galls, five of sulphate of iron, and thirty of logwood, for every 100 of cloth. For coarse cloths the previous blue dye is omitted. The cloth is then washed and fulled.

Silk is dyed black as follows. After boiling it with soap, it is galled, and afterwards washed. It combines with a considerable portion of the astringent principle, and increases in weight. It is then dipped into a bath of sulphate of iron and gum arabic.

Cotton and *linen* are first dyed blue, then steeped in a decoction of galls, and alder bark. It is then put into a bath of acetite of iron, taken out and exposed to the air. This operation is repeated several times.

Of dyeing Compound Colours.

Compound colours are produced either by mixing together two or more simple ones, or by dyeing cloth first one simple colour and afterwards another.

Greens are formed of blues and yellows. Wool is dyed green by dyeing it first blue of a depth of shade sufficient for the required kind of green. It is then washed and boiled in a bath of weld and tartar, or any of the processes used for dyeing blue and yellow may be used. Various shades will be given by different proportions of the dyeing materials. The green called *Saxon green* is obtained by solutions of indigo in sulphuric acid, sometimes quercitron bark is used. Another process for Saxon green is by the quercitron bark, and then a bath of the murio-sulphate of tin and alum with sulphate of indigo.

Purples, violets, &c.—All the shades of these colours are formed of blue and red. Sometimes the cloth is dyed blue and then scarlet, and sometimes cochineal is mixed with sulphate of indigo, and the purple dyed at once. Silk is dyed first by cochineal and afterwards by indigo. Cotton and linen are dyed blue, then galled, and boiled in logwood.

Orange colours are produced by mixtures of yellow and red. Wool is first dyed scarlet and then yellow.

Olive is blue combined with red and yellow.

Cinnamon colour is given to wool by dyeing it first with madder, then yellow. Silk is dyed the same colour by logwood, Brazil-wood, and fustic. Cotton and linen receive a cinnamon colour by weld and madder.

Brown is given to cloth by quercitron bark, or by walnut peels.

When walnut peels, or the green covering of the walnut, are first separated, they are white internally, but soon assume a brown or even a black colour on exposure to the air. They readily give up their colouring matter to water. It is common to keep them in water for a year before they are used. Wool is dyed brown with them by steeping in a decoction for a length of time proportioned to the depth of colour required. The same colouring matter is found in the root of the walnut-tree, but in smaller quantity. Other trees, as the bark of the birch may be used for dyeing browns, and in these cases it is probable that the colouring matter is combined with the tanning principle, and this may be the reason why no mordant is necessary, both the cloth and colouring matter having a strong affinity for tannin.

Drab colours are dyed by combining brown oxide of iron with the cloth, and then the yellow of quercitron bark. The strength of shade will be more or less, by varying the quantity of the mordant, when the proportion is small the colour inclines to olive or yellow, on the contrary the drab may be deepened or saddened, as the dyers term it, by mixing a little sumach with the bark.

CALICO PRINTING.

Calico is a species of cotton cloth ornamented with coloured patterns. The name is derived from Calicut, a district of India, where it was first made, and from whence it was formerly imported. The art of making calicoes had been practised there from time immemorial, but it is scarcely a hundred years since it was known in Europe; it has already risen to such perfection as to equal if not exceed the manufactures of India, in the elegance of the patterns, the beauty and permanance of the colours, and the expedition with which the different operations are carried on.

The process of calico-printing consists in impregnating those parts of the cloth which are to receive the coloured pattern with a mordant, and then dyeing the cloth by the usual methods. The dye is firmly fixed to that part only where the mordant has been applied; and, although the whole cloth has received the tint, yet the colour will be easily discharged from the unmordanted parts by washing, and exposing on the grass to the sun and air for some days with the wrong side uppermost. Thus, suppose a pattern had been applied to white cloth with a solution of acetite of alumine, and that then the whole was dyed with madder; when taken out of the dye-vat the whole cloth would be red; but, by washing and bleaching, the madder will be discharged from every part of the cloth except where the acetite of alumine had been applied; and, consequently, the pattern alone will appear red. In the same manner the patterns may be applied of any other colour by varying the dye, as quercitron bark or weld for yellow, &c.

Two mordants are particularly employed in calico-printing, acetite of alumine, and iron dissolved in some vegetable acid.

The acetite of alumine is made by a double decomposition of alum and sugar of lead. When iron is used as a mordant, it is dissolved in vinegar, soured beer, or pyroligneous acid; and it is, therefore, an acetite of iron mixed with a portion of tartrite, gallate, and, perhaps, other salts of the metal.

When the colour of the required pattern varies in different places, this effect is produced on the cloth, by impregnating the several parts with various mordants. Thus, if one part is printed with acetite of alumine, and another with acetite of iron, and the whole cloth afterwards dyed with madder and bleached, the pattern will appear in red and brown.

The mordants are applied to the cloth either by a pencil, or by means of blocks on which the pattern is cut. Care must be taken that the printing from the block does not spread, or that the impressions from the several blocks do not interfere with one another when more than one is applied. For this purpose it is necessary, that the substance used as mordants should have a degree of consistence that may prevent them from spreading. Flour paste, or starch, is mixed with the mordant when it is applied by blocks, and gum arabic when it is but on by a pencil. This thickening requires exactness: if too little is used, the pattern will spread; and, if too much, the cotton will not receive a sufficient quantity of the mordant, and will take the dye imperfectly.

In order that the impression given by the blocks with the mordant may be seen easily before it is dyed, the mordant is tinged with some colouring matter that will not remain fixed. Decoction of Brazil-wood is used for this purpose.

Before printing, the cotton cloth is well bleached and calendered, and laid smooth on a table: the blocks are applied by hand, and struck with a mallet. The cotton is then dried well in a room with a stove, which not only fixes the mordant more securely, but drives off part of the acetous acid from its base, by which the mordant will combine in a greater proportion, and more intimately with the cloth.

To discharge the paste and gum used with the mordant, the cloth is next to be washed with warm water and cow-dung; this, also, discharges such parts of the mordant as are not properly fixed, enough being still left to fix the dye. The cloth is then rinsed in clear water. It is then dyed in the usual manner.

The principal dye-stuffs used by calico-printers are indigo, madder, quercitron bark, and weld.

After dyeing, the cloth is well washed, exposed on the grass, and bleached; by which all the parts not touched by the mordant are restored to their original whiteness.

In this manner various colours may be given by one dyeing, merely by varying the mordant. Thus, if one pattern be printed with alum alone, a second with a mixture of alum and iron liquor, a third with iron liquor alone, and a fourth with iron liquor and galls, and the piece be afterwards dyed with quercitron or weld, and the ground bleached in the usual manner; the first pattern will be pure yellow, the second will be olive, the third of a dark drab colour, and the fourth nearly black, while the ground will be white.

As indigo does not require any mordant, it is applied at once, either by a pencil or by a block and paste. But, as has been mentioned under dyeing, indigo will not combine with the cloth except in its disoxygenated or green state; and, if applied thus by the pencil, it would return to the blue state before it had time to fix upon the stuff. The indigo is, therefore, prepared by boiling with potash, made caustic by quicklime, to which is added orpiment for the disoxygenation of the indigo. This solution is thickened with gum. It must be excluded from the air, otherwise it would attract oxygen and return to the blue or insoluble state. Dr. Bancroft proposed substituting brown sugar for orpiments, as it is equally efficacious in disoxygenating the indigo, and will also serve instead of gum.

Some calicoes are printed only with one colour; others have two; others three, or more, even to the number of eight, ten, or twelve. The smaller the number of colours, the fewer are the processes. To give an example where six colours are used.

1. A nankeen yellow, of various shades down to a deep yellowish brown or drab, is given by acetite of iron put on with gum or paste, and afterwards plunged into the potash ley.

2. Yellow, by a mordant of acetite of alumine, the dyeing by quercitron bark and bleaching.

3. Red, by the last process, only madder is substituted for the bark.

4. Light blue is given by making a block for all those parts that are to be white, and printing by it on the cloth a composition of which wax is the principal ingredient, or pipe-clay and paste. The cloth is then dyed in a cold indigo vat, and the wax removed by hot water.

5. Lilac flea-brown, and blackish brown, are given by acetite of iron, and dyeing afterwards with madder.

6. Dove-colour and drab, by acetite of iron and quercitron bark.

The same mordant will frequently do for several colours. Thus, suppose one part of the cloth should be printed with acetite of alumine, another with acetite of iron, and a third with a mixture of these two mordants, and the whole afterwards dyed with quercitron bark; then the following colours would appear, viz. yellow, drab, olive; and various depths of shade will be given by varying the proportions of iron in the mordant.

If some parts of the yellow be covered over with the indigo liquor, applied with a pencil, it will be converted into green. By the indigo, also, any parts that are required to be blue may be pencilled.

If, instead of quercitron bark, the cloth printed with the three mordants just mentioned be dyed with madder, then the colours exhibited will be red, brown or black, and purple.

Other processes are still more complicated when a great number of colours are required. New mordants are applied to parts of the pattern already printed, and the cloth again dyed, by which those parts only receive a new colour.

Sometimes the dye stuff and the mordant are mixed together in the first instance, and printed on the cloth, which is a great saving of time and expense; but the colours thus produced on the cloth are not permanent: washing, or even exposure to the air frequently destroys them.

TANNING.

Tanning is the art of converting the raw skins of animals into *leather*.

The skin is composed chiefly of two parts, a thin white elastic layer on the outside, which is called the *epidermis*, or *cuticle*; and a much thicker layer, composed of a great many fibres, closely interwoven, and disposed in different directions: this is called the *cutis*, or *true skin*.

The epidermis is that part of the skin which is raised in blisters. It is easily separated from the cutis by maceration in hot water. It possesses a very great degree of elasticity. It is totally insoluble in water and alcohol. Pure fixed alcalis dissolve it completely, as does lime likewise though slowly.

When a portion of cutis is macerated for some hours in water, with agitation and pressure, the blood, and all the extraneous matter with which it was loaded, are separated from it, but its texture remains unaltered. On evaporating the water employed, a small quantity of gelatine may be obtained. No subsequent maceration in cold water has any farther effect; the weight of the cutis is not diminished, and its texture is not altered; but if it be boiled in a sufficient quantity of water, it may be completely dissolved, and the whole of it, by evaporating the water, obtained in the state of *gelatine.*

It was mentioned, when treating of chemistry, that gelatine with *tannin,* or the *tanning principle* of vegetables, formed a combination, which is insoluble in water. Upon this depends the art of making *leather;* the gelatinous part of the skin combining with the tannin of the bark usually employed.

The process which has long been used in this country is as follows; the leather tanned in England consists chiefly of three sorts, known by the name of *butts* or *backs, hides,* and *skins. Butts* are generally made from the stoutest and heaviest ox hides, and are managed as follows: after the horns are taken off, the hides are laid smooth in heaps for one or two days in the summer, and for five or six in the winter; they are then hung on poles, in a close room called a *smoke-house,* in which is kept a smouldering fire of wet tan; this occasions a small degree of putrefaction, by which means the hair is easily got off, by spreading the hide on a sort of wooden horse or beam, and scraping it with a crooked knife. The hair being taken off, the hide is thrown into a pit or pool of water, to cleanse it from the dirt, &c. which being done, the hide is again spread on the wooden beam, and the grease, loose flesh, extraneous filth, &c. carefully scrubbed out or taken off; the hides are then put into a pit of strong liquor, called *ooze*, prepared in pits kept for the purpose, by infusing ground bark in water; this is termed *colouring;* after which they are removed into another pit called a *scowering*, which consists of water strongly impregnated with vitriolic acid, or with a vegetable acid, prepared from rye or barley. This operation (which is called *raising*), by distending the pores of the hides, occasions them more readily to imbibe the ooze, the effect of which is to combine with the gelatinous part of the skin, and form with it *leather*. The hides are then taken out of the scowering, and spread smooth in a pit commonly filled with water, called a *binder*, with a quantity of ground bark strewed between each. After laying a month or six weeks, they are taken up; and the decayed bark and liquor being drawn out of the pit, it is filled again with strong ooze, when they are put in as before, with bark between each hide. They now lie two or three months, at the expiration of which the same operation is repeated; they then remain four or five months, when they again undergo the same process, and after being three months in the last pit, are completely tanned; unless the hides are so remarkably stout as to want an additional pit or layer. The whole process requires from eleven to eighteen months, and sometimes two years, according to the substance of the hide, and discretion of the tanner. When taken out of the pit to be dried, they are hung on poles, and after being compressed by a steel pin, and beat out smooth by wooden hammers, called *batts*, the operation is complete; and when thoroughly dry, they are fit for sale. Butts are chiefly used for the soles of stout shoes.

The leather which goes under the denomination of *hides*, is generally made of cow hides, or the lighter ox hides, which are thus managed. After the horns are taken off, and the hides washed, they are put into a pit of water, saturated with lime, where they remain a few days, when they are taken out, and the hair scraped off on a wooden beam, as before described; they are then washed in a pit, or pool of water, and the loose flesh, &c. being taken off, they are removed into a pit of weak ooze, where they are taken up, and put down (which is technically termed *handling*) two or three times a-day, for the first week; every second or third day they are shifted into a pit of fresh ooze, somewhat stronger than the former; till at the end of a month or six weeks they are put into a strong ooze, in which they are handled once or twice a-week with fresh bark for two or three months. They are then removed into another pit, called a *layer*, in which they are laid smooth, with bark ground very fine, strewed between each hide. After remaining here two or three months, they are generally taken up, when the ooze is drawn out, and the hides put in again with fresh ooze and fresh bark, where, after lying two or three months more, they are completely tanned, except a few very stout hides, which may require an extra layer: they are then taken out, and hung on poles, and being hammered and smoothed by a steel pin, are, when dry, fit for sale. These hides are called *crop hides;* they are from ten to eighteen months in tanning, and are used for the soles of shoes.

Skins is the general term for the skins of calves, seals, hogs, dogs, &c. These, after being washed in water, are put into lime pits, as before mentioned, where they are taken up and put down every third or fourth day, for a fortnight or three weeks, in order to destroy the epidermis of the skin. The hair is then scraped off, and the excrescences being removed, they are put into a pit of water impregnated with *pigeon dung*, called a *grainer*, forming an alcaline ley, which in a week or ten days soaking out the lime, grease, and saponaceous matter (during which period they are several times scraped over with a crooked knife, to work out the dirt and filth), softens the skins, and prepares them for the reception of the ooze. They are then put into a pit of weak ooze, in the same manner as the hides, and being frequently handled, are by degrees removed into a stronger, and still stronger liquor, for a month or six weeks, when they are put into a very strong ooze, with fresh bark ground very fine, and at the end of two or three months, according to their substances, are sufficiently tanned: when they are taken out, hung on poles, dried, and are fit for sale. These skins are afterwards dressed and blacked by the curriers, and are used for the upper leathers of shoes, boots, &c.

The lighter sort of hides, called *dressing hides*, as well as horse hides, are managed nearly in the same manner as skins; and are used for coach-work, harness work, &c. &c.

As the method of tanning above described, and all others in general use, are extremely tedious and expensive in their operation, various schemes at different times have been suggested to shorten the process, and lessen the expense.

Much light has been thrown by modern chemists upon the theory of tanning, and considerable improvements have been made in the practice of this art. M. Seguin, in France, has particularly distinguished himself by his researches on this subject, and much improved the art in his country.

In 1795, Mr. William Desmond obtained a patent for practising Seguin's method in England. He obtained the tanning principle, by digesting oak bark, or other proper material in cold water, in an apparatus nearly similar to that used in the saltpetre works: that is to say, the water which has remained upon the powdered bark for a certain time, in one vessel, is drawn off by a cock, and poured upon fresh tan: this is again to be drawn off, and poured upon other fresh tan; and in this way the process is to be continued to the fifth vessel. The liquor is then highly coloured, and and marks from six to eight degrees upon the hydrometer for salts. This he calls the tanning lixivium.

The criterion for ascertaining its strength is the quantity of the solution of gelatine which a given quantity of it will precipitate. Isinglass is used for this purpose, being entirely composed of gelatine. And here it may be observed, that this is the mode of ascertaining the quantity of tanning principle in any vegetable substance, and, consequently, how far they may be used as a substitute for oak bark.

The hides, after being prepared in the usual way, are immersed for some hours in a weak tanning lixivium of only one or two degrees; to obtain which, the latter portions of the infusions are set apart, or else some of that which has been partly exhausted by use in tanning. The hides are then to be put into a stronger lixivium, where, in a few days, they will be brought to the same degree of saturation with the liquor in which they are immersed. The strength of the liquor will by this means be considerably diminished, and must, therefore, be renewed. When the hides are by this means completely saturated, that is to say, perfectly tanned, they are to be removed, and slowly dried in the shade.

It has been proposed to use the residuum of the tanning lixivium, or the exhausted ooze (which contains a portion of Gallic acid, this forming a constituent part of astringent vegetables), for the purpose of taking off the hair; but this liquor seems to contain no substances capable of acting upon the epidermis, or of loosening the hair; and when skin is taken off by being exposed to it, the effect must really be owing to incipient putrefaction.

The length of time necessary to tan leather completely, according to the old process, is certainly a very great inconvenience; and there is no doubt but that it may be much shortened by following the new method. It has been found, however, that the leather so tanned has not been so durable as that which has been formed by a slower process.

The public is much indebted to Sir Humphry Davy, for the attention which he has paid to this subject. From his excellent paper "On the Constituent Parts of Astringent Vegetables," in the Philosophical Transactions, we present the reader with the following extract.

"In considering the relation of the different facts that have been detailed, to the processes of tanning and of leather-making, it will appear sufficiently evident, that when skin is tanned in astringent infusions that contain, as well as tannin, extractive matters, portions of these matters enter, with the tannin, into chemical combination with the skin. In no case is there any reason to believe that gallic acid is absorbed in this process; and M. Seguin's ingenious theory of the agency of this substance, in producing the de-oxygenation of skin, seems supported by no proofs. Even in the formation of glue from skin, there is no evidence which ought to induce us to suppose that it loses a portion of oxygen; and the effect appears to be owing merely to the separation of the gelatine, from the small quantity of albumen with which it was combined in the organized form, by the solvent powers of water.

"The different qualities of leather made with the same kind of skin, seem to depend very much upon the different quantities of extractive matter it contains. The leather obtained by means of infusions of galls, is generally found harder, and more liable to crack, than the leather obtained from the infusion of barks; and in all cases it contains a a much larger proportion of tannin, and a smaller proportion of extractive matter.

"When skin is very slowly tanned in weak solutions of the barks, or of catechu, it combines with a considerable proportion of extractive matter; and in these cases, though the increase of weight of the skin is comparatively small, yet it is rendered perfectly insoluble in water, and is found soft, and at the same time strong. The saturated astringent infusions of barks contain much less extractive matter, in proportion to their tannin, than the weak infusions; and when skin is quickly tanned in them, common experience shows that it produces leather less durable than the leather slowly formed.

"Besides, in the case of quick tanning by means of infusions of barks, a quantity of vegetable extractive matter is lost to the manufacturer, which might have been made to enter into the composition of his leather. These observations show, that there is some foundation for the vulgar opinion of workmen, concerning what is technically called the *feeding* of leather in the slow method of tanning; and though the processes of the art may in some cases be protracted for an unnecessary length of time, yet, in general, they appear to have arrived, in consequence of repeated practical experiments, at a degree of perfection which cannot be very far extended by means of any elucidations of theory that have as yet been known."

As a vast quantity of bark may easily be obtained in countries that are covered with natural forests, such as many parts of America, New Holland, &c. it has been suggested, as a method of lessening the expense of freight in bringing it over, to make an extract from the bark, which might be very easily transported, and which would serve the purpose of the tanner as well as the bark itself.

It was first suspected by Sir Joseph Banks, and afterwards confirmed by the experiments of Sir Humphry Davy, that a substance called *catechu*, or *terra Japonica*, brought from the East Indies, contained a vast quantity of tannin; so much so, that it far excels every other known substance in this respect. One pound of catechu contains as much tannin as eight or ten pounds of common oak bark, and would consequently tan proportionately as much more leather. It is an extract made from the wood of a species of mimosa, by decoction and subsequent evaporation.

Oak bark being a very expensive article in the process of tanning, various substances have been proposed as substitutes for it. All the parts of vegetables which are of an astringent nature, contain tannin (which may be known by their giving precipitates with gelatine, insoluble in water), and will answer this purpose. The leaves, branches, fruit, flowers, of a vast number of plants; every part of the oak, as the leaves and acorns, oak saw-dust, and the barks of almost all trees, contain more or less tannin.

Mr. Biggins made a great many experiments upon the quantity of tanning principle in various barks, from which he constructed the following table.

	Tanning principle (in grains), from half a pint of infusion and an ounce of solution of glue.
Bark of elm,	28
oak, cut in winter,	30
horse-chesnut,	30
beech,	31
willow (boughs)	31
elder,	41
plum-tree,	58
willow (trunk),	52
sycamore,	53
birch,	54
cherry-tree,	59
sallow,	59
mountain-ash,	60
poplar,	76
hazel,	79
ash,	82
Spanish chesnut,	98
smooth oak,	104
oak, cut in spring,	108
Huntingdon, or Leicestershire willow,	109
sumach,	158

CURRYING.

The art of currying consists in rendering tanned skins supple and of uniform density, and impregnating them with oil, so as to render them in a great degree impervious to water.

The stronger and thicker hides are usually employed for making the soles of boots and shoes, and these are rendered fit for their several purposes by the shoemakers after they are tanned; but such skins as are intended for the upper leathers and quarters of shoes, for the legs of boots, for coach and harness leather, saddles, and other things, must be subjected to the process of currying.

These skins after coming from the tanners, having many fleshy fibres on them, are well soaked in common water. They are then taken out and stretched upon a very even wooden horse; where with a paring knife all the superfluous flesh is scraped off, and they are again put into soak. After the *soaking* is completed the currier takes them again out of the water, and having stretched them out, presses them with his feet, or a flat stone fixed in a handle, to make them more supple, and to press out all the filth that the leather may have acquired in tanning, and also the water it has absorbed in soaking.

The skins are next to be *oiled*, to render them pliant and impervious to wet. After they are half dried, they are laid upon tables, and first the grain side of the leather is rubbed over with a mixture of fish oil and tallow; then the flesh side is impregnated with a large proportion of oil. After having been hung up a sufficient time to dry, they are taken down and rubbed, pressed, and folded in various directions, and then spread out, when they are rolled with considerable pressure upon both sides with a fluted board fastened to the operator's hand by a strap; by this means, and by repeating the rolling, a grain is given to the leather.

After the skins are curried, it may be required to colour them. The colours usually given to them are black, white, red, green, yellow, &c.

If the skins are to be blacked, the process varies according to the side of the skin to be coloured. Leather that is to be blacked on the flesh side, which is the case with most of the finer leather intended for shoes and boots, is coloured with a mixture of lamp black, oil, and tallow, rubbed into the leather. And what is to be coloured on the grain side is done over with chamber lye, and then with a solution of sulphate of iron, which turns it black.

MANUFACTURE OF SODA.

Soda, or the mineral alcali, (described above, under Chemistry) is sometimes found in a native state, as in the lakes of Natron in Egypt, which are dry in the summer season; the water leaving after evaporation a bed of soda, or, as it is there called, *natron*, of two feet in thickness.

A marine plant, called the *Salsola soda*, which grows among the cliffs on the sea coast, seems to be endowed by nature with the property of decomposing the salt water, that is, of separating the muriatic acid from the soda, which latter it absorbs. This plant is collected by the Spaniards with great care, and burnt for the manufacture of *barilla*, which is a carbonate of soda mixed with various impurities.

Soda is also procured in a still more impure state, by the burning of the sea weeds on our own shores, particularly in Scotland, from which is produced a substance called *kelp*.

But the demand for a pure carbonate of soda having become very considerable of late years, from its great utility in many arts and processes, various means have been tried for procuring it by decomposing the salts, in which it exists, combined with acids. Muriate of soda has been decomposed for this purpose. The following method is described in Nicholson's Journal.

Solutions of 500lbs. of sulphate of soda*, and 560lbs. of American potash, are made to boil, and are then mixed. As soon as the mixture boils, it is conveyed into a cistern of wood, lined with lead, half an inch thick, which is fixed in a cool place. Sticks of wood are then placed across the cistern, from which slips of sheet lead, two or three inches wide, are hung into the fluid, at four inches distance from each other. When all is cool, the fluid is let off, and the chrystallized salt is detached from the slips of lead, and the bottom of the trough. The salt is then washed, to free it from impurities, after which it is transferred again into the boiler, dissolved in clear water, and evaporated by heat. As soon as a strong pellicle is formed, it is suffered to cool so far that the hand may be dipped into it without injury, and the heat is kept at that temperature as long as effectual pellicles continue to be formed over the whole surface of the boiler, and then fall to the bottom. When no more are formed, the fire is withdrawn, and the fluid ladled out into the cistern to crystallize. The sulphate of potash, &c. which had been deposited, is then taken out of the boiler, and put aside. By this process from 136 to 139lbs. of soda may be obtained from 100lbs. of sulphate of soda.

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* Sulphate of soda is sold cheap by the bleachers, who save it as the residue in decomposing common salt by sulphuric acid with manganese.

MANUFACTURE OF POTASH.

Potash, or the fixed vegetable alcali, exists as an ingredient, in very small quantity, in many minerals. It is also obtained from the tartar, or from lees of wine, in which it is called *salt of tartar*.

But the great supply of this substance is procured from the ashes of burnt vegetables.

In many districts of England and Ireland they burn the common fern to ashes, which they mould up with a little water, into balls of about three or four inches in diameter; these are called *ash balls*; and are the rudest preparation of this alcali.

The potash of commerce, or *black potash*, is always procured from the combustion of wood; and can, therefore, only be made in those countries where wood is very plentiful, as Poland, Russia, and Germany. This country is chiefly supplied from America. The ashes of burnt wood are put into a cistern with water, and a strong lixivium is made. After a time, the water, holding the alcali in solution, is drawn off, leaving the impurities behind.

Potash is converted into a purer state by calcining it in a reverberatory furnace. It becomes then dry, porous, considerably caustic, extremely deliquescent, and of a beautiful bluish colour, from which it is called *pearl ash*.

All these are carbonates of potash.

To obtain potash in a state of perfect purity, or uncombined with carbonic acid, the carbonate must be boiled with twice its weight of quicklime to deprive it of the carbonic acid; then to free it from other impurities, it must be dissolved in spirits of wine, (which dissolves alcalis and no other salt) and the solution evaporated to dryness. It is then pure and powerfully caustic.

REFINING METALS.

The term refining signifies the purification of some substance: but we mean to confine it at present to the separation of gold, silver, and copper from each other, and obtaining each of them in a pure state.

Cupellation.

Gold and silver being the only metals capable of withstanding the action of very strong heat, are therefore called *perfect* metals. All other metals are reduced to the state of oxides when exposed to a violent fire with access of air. Gold and silver may, therefore, be purified from all the baser metals by keeping them fused till the alloy be destroyed: but this process would be very expensive, from the great consumption of fuel, and would be exceedingly tedious. A shorter and more advantageous method of performing this operation has been discovered.

A certain quantity of lead is added to the alloy of gold and silver, and the whole is exposed to the action of the fire.

Lead is one of the metals which is most quickly converted by heat into an oxide, which is easily melted into a semi-vitrified, and powerful vitrifying matter, called litharge. By increasing the proportion of imperfect metals, it prevents them from being so well covered and protected by the perfect metals; and by uniting with these imperfect metals, it communicates to them its property of being very easily oxidated. By its vitrifying and fusing property, which it exercises with all its force upon the calcined and naturally refractory parts of the other metals, it facilitates and accelerates the fusion, scorification, and separation of these metals. The lead, which in this operation is scorified, and scorifies along with it the imperfect metals, separates from the metallic mass with which it is then incapable of remaining united. It floats upon the surface of the melted mass, and becomes semi-vitrified. But the litharge so produced would soon cover the melted metal, and by preventing the access of air would prevent the oxidation of the remaining imperfect metals. To remedy this, such vessels are employed as are capable of imbibing and absorbing in their pores, the melted litharge, and thus remove it out of the way; or, for large quantities, vessels are so constructed, that the fused litharge, besides being soaked in, may also drain off, through a channel made in the corner of the vessel.

Experience has shown that for this purpose, vessels made of lixiviated wood or bone-ashes are most proper. These vessels are called *cupels*, and this process is called *cupellation*. The cupels are flat and shallow. The furnace ought to be vaulted, that the heat may be reverberated upon the surface of the metal during the whole time of the operation. Upon this surface a crust or dark coloured pellicle is continually forming. In the instant when all the imperfect metal is destroyed, and, consequently, the scorification ceases, the surface of the perfect metal is seen, and appears clean and brilliant. This forms a kind of fulguration, or corruscation, called lightning. By this mark the metal is known to be refined.

Purification of gold by antimony.

When gold contains only a small quantity of alloy, it may be separated from them by melting it in a crucible that will hold twice its quantity at least, and throwing upon it, whilst in fusion, twice its weight of crude antimony (sulphuret of antimony). The crucible is then to be covered, and the whole is to be kept in a melting state for some minutes; and when the surface sparkles, it is quickly to be poured into an inverted cone, which has been previously heated and greased. By striking the cone on the ground, the metal will come out when cold. The compact mass consists of two substances; the upper part is the sulphur of the crude antimony, united with the impure alloy; and the lower part is the gold, united to some of the regulus of antimony, proportionable to the quantities of metals which have been separated from the gold, which are now united with the sulphur of the antimony. This regulus of gold may be separated from the regulus of antimony by simple exposure to less heat than will melt the gold, because antimony is volatile in such a heat, and is then dissipated. If the gold is not sufficiently purified by this first process (which is often the case,) it must be repeated a second, and even a third time. When a part is dissipated, more heat is required to keep the gold in fusion; therefore, the fire must be increased towards the end of the operation. The purification is completed by means of a little nitre thrown into the crucible, which effectually calcines the remaining regulus of antimony. Sometimes, after these operations, the gold is found to be deprived of much of its usual ductility; this however is easily restored to it, by fusing it with nitre and borax. The first part of this process is founded on a property of sulphur, by which it is incapable of uniting with gold, and is strongly disposed to unite with all other metallic substances, excepting platina and zinc; and also upon the property of sulphur, that it has less affinity with regulus of antimony than with any metallic substance with which it can unite. Hence, when gold, alloyed with silver, copper, iron, lead, &c. is fused together with sulphuret of antimony, these latter metals unite with the sulphur of the antimony, while the reguline part, disengaged from them by its sulphur, unites with the gold.

The sulphur of the antimony, though it unites with the baser metals, does not destroy them, but forms with them a scoria, from which they may be separated by treatment as an ore.

Parting.

When the quantity of silver united to the gold is considerable, they may be separated by other processes. Nitric acid, muriatic acid, and sulphur, which cannot dissolve gold, attack silver very easily; and, therefore, these three agents furnish methods of separating silver from gold, which operation is called *parting*.

Parting by nitric acid is the most convenient, and, therefore, most used; and is even almost the only one employed by goldsmiths and coiners. Wherefore it is called simply, *parting*. That made with muriatic acid is only made by cementation, and is known by the name of *concentrated parting*.

Lastly, parting by sulphur is made by fusion, and is, therefore, called *dry parting*.

Parting gold from silver by nitric acid or aqua fortis.—Although parting by nitric acid be easy, it cannot succeed, or be very exact, unless we attend to some essential circumstances. The gold and silver must be in a proper proportion; for if the gold be in too great a quantity, the silver would be covered and guarded by it from the action of the acid; therefore, when assayers do not know the proportion of gold to silver in the mass; they rub the mass upon a *touch-stone* (which is usually composed of black basalt; though black pottery will do very well;) so as to leave a mark upon it; they then make similar marks with the *proof-needles*, (which are needles composed of gold and silver alloyed together in graduated proportions;) and by comparing the colour of the several marks, they discover the probable scale of admixture.

If the trial shows that in any given mass the silver is not to the gold as three to one, this mass is improper for the operation of parting by aqua fortis. In this case, the quantity of silver necessary to make any alloy of that proportion must be added. This operation is called *quartation*, because it reduces the gold to a fourth of the whole mass. No inconvenience arises from too great quantity of silver, except a waste of aqua fortis. The nitric acid, or aqua fortis employed, must be very pure, and especially free from mixture of sulphuric and muriatic acids. Its purity must, therefore, be ascertained; and if this be found not sufficient, the acid must be purified by nitrate of silver.

If the purity of the nitric acid were not attended to, a quantity of silver proportionable to these two foreign acids, would be separated during the solution; and this portion of silver converted by these acids to sulphate of silver, and to muriate of silver, would remain mingled with the gold.

When the metallic mass is properly alloyed, it is to be reduced to plates rolled up spirally, called *cornets*, or to grains. These are to be put into a matrass, and upon them a quantity of aqua fortis is to be poured, the weight of which is to that of the silver as three to two; and as the nitric acid employed for this operation is rather weak, the solution is assisted, especially at first, by the heat of a sand-bath, in which the matrass is to be placed. When, notwithstanding the heat, no further mark of solution appears, the aqua fortis charged with silver is to be decanted. Fresh nitric acid is to be poured into the matrass, stronger than the former, and in less quantity, which must be boiled in the remaining mass, and decanted as the former. Aqua fortis must even be boiled a third time on the remaining gold, that all the silver be certainly dissolved. The gold is then to be washed with boiling water. This gold is very pure, if the operation has been performed with due attention. It is called gold of parting.

The silver dissolved in the aqua fortis may be separated either by distillation—in which case all the aqua fortis is recovered very pure, and fit for another parting—or it may be precipitated by some substance which has a greater affinity than this metal with nitric acid. Copper is generally employed for this purpose in the mint.

The solution of silver is put into copper vessels. The aqua fortis dissolves the copper, and the silver precipitates. When the silver is all precipitated, the new solution is decanted, which is then a solution of copper. The precipitate is to be well washed, and may be melted into an ingot. It is called parted silver. When this silver has been obtained from a mass which had been refined by lead, and when it has been well washed from the solution of copper, it is very pure. Or the silver may be separated from the nitric acid by adding to it muriatic acid, with which it forms muriate of silver. Muriate of silver may be decomposed by mixing it with soda, and exposing it to a sufficient heat in a crucible, whereby the soda unites to the muriatic acid, and sets the silver free.

The refiners frequently employ this solution of copper obtained in the process of parting, for making *verditer;* which is prepared by adding quick lime to the solution; a precipitate takes place, which is the blue pigment known by the name of verditer.

Parting gold from silver by cementation.—This is also called parting by concentration, and is usually employed when the quantity of gold is so great to that of the silver, as to render it a difficult task by aqua fortis. The mixed metal to be cemented is to be reduced to plates, as thin as small pieces of money. At the bottom of the crucible, or melting-pot, is to be laid a stratum of cement, composed of four parts of bricks powdered and sifted, one part of green copperas (sulphate of iron) calcined to redness, and one part of common salt, about the thickness of a finger in depth. Upon this stratum a layer of plates of the metal is to be placed, and then another stratum of cement, and so on till the crucible is filled. It is now to be placed in a furnace, or oven (after a top has been luted on the crucible,) and exposed for twenty-four hours, till it is gradually made red hot, but by no means to be melted. The fire is now left to go out, and the metal is permitted to cool, that it may be separated from the cement, and bolled repeatedly in large quantities of pure water. This gold is afterwards to be tried on a touch-stone; and if it is not sufficiently purified, the process must be performed a second time. By the above method, we see how powerfully silver is dissolved by muriatic acid, when it is in a state of subtile vapour which is disengaged from the common salt of the cement. Instead of common salt, nitre may be used, as the nitrous acid readily dissolves silver; but the mixture of common salt and nitre together is highly injudicious, because the joint acids are able to dissolve some of the gold with the silver. Whatever silver has been separated, will now remain in the cement; but it may be freed from this by lead, in the method described in cupellation.

Parting gold from silver in the dry way.—This is also called *parting by fusion*, and is performed by means of sulphur, which has the property of uniting easily with silver, while it does not attack gold. This dry parting is troublesome, and even expensive, and ought not to be undertaken but when the silver far exceeds the gold, because sulphur will not separate it so easily as aqua fortis, and will therefore require a further application to cupellation and solution.

Refining Silver by Nitre.

The principle upon which this operation is founded, consists in the property of nitre to oxydate very powerfully all base metals; whereas, on the contrary, the noble metals are not at all affected by it. For as the metallic oxides and glasses do not remain united with reguline metals, and as these latter sink to the bottom when in fusion, on account of their greater specific gravity, they may be easily parted from the scoriæ.

The silver to be purified by nitre is to be first granulated, and then mixed with a fourth part of its weight of dry nitre, an eighth part of potash, and a little common glass, all in powder. This mixture is to be put into a good crucible, two-thirds of which only must be full. This crucible is to be covered with a smaller crucible inverted, in the bottom of which a small hole has been made, and luted to the former. The crucibles, thus disposed, are to be placed in a furnace capable of drawing air sufficiently to make the fire intense enough only to melt the silver. Then charcoal is to be put into the furnace to such a height, that only the top of the inverted crucible shall be uncovered. The coal is then to be kindled, and the vessels to be made moderately red; a hot coal ought to be put upon the small hole in the bottom of the inverted crucible. If a shining light be observed round this coal, and a slight hissing noise at the same time heard, we may know that the operation proceeds well. The fire must be sustained at the same degree till these appearances cease, when it must be increased, so that the silver be well melted, and then the crucibles are to be taken out of the furnace. The larger crucible is to be broken when it is cold, and the silver will be found at the bottom covered with green alcaline scoriæ. If the metal be not sufficiently ductile, the operation must be again repeated.

Some silver is apt to be lost in this operation, by the swelling and detonation of the nitre, which often forces it through the hole in the upper crucible, unless great care be used; nevertheless, this method has its advantages, being much more expeditious than cupellation.

Separating Silver from Copper by Eliquation.

When it is desired to separate, in the large way, a small quantity of silver from much copper with which it is alloyed, the process called *eliquation* is resorted to. This operation is grounded on the nearer affinity of silver with lead than with copper; in consequence of which it fuses, and combines with lead at a degree of heat in which copper continues unfused.

Whitening Silver by Boiling.

Whitening of silver by boiling is one of the methods of parting copper from silver in the humid way. For this purpose, silver wrought in any shape is first ignited to redness, and afterwards boiled in a ley of muriate of soda, and acidulous tartrite of potash. By so doing, the copper is removed from the surface, and the silver receives a better appearance.

Precipitating Silver by Copper.

Copper has a much greater affinity with oxygen than silver; consequently, the silver is precipitated from its solutions as a fine *silver dust*, by metallic copper. This likewise affords a means to discover what portion of silver may be contained in an alloy of silver and copper. A quantity of the mixture determined by weight is dissolved in nitric acid;

the solution is diluted with water, filtered, and a plate of copper hung in it, till no more precipitate falls down. Then the weight of the precipitate, when edulcorated, is compared with that of the whole alloyed metal put to trial.

This silver dust well washed, and mixed with gum water, serves as a pigment in water painting.

Separating Silver from Copper by an Alcaline Sulphuret.

The affinity of copper with sulphur is stronger than that of silver. Upon this ground, liver of sulphur (sulphuret of potash) has been proposed as an expedient to free silver from copper; for if silver holding copper be fused with alcaline sulphuret, the base metal combines with the latter, and is converted into scoriæ floating on the silver.

Mr. Keir's Mode of separating Silver from Copper.

Chemists have long been acquainted with the compound acid, called *aqua regia* (nitro-muriatic acid), which has the exclusive property of dissolving gold. The discovery of a compound acid, acting exclusively upon silver, is owing to Mr. Keir.

This compound acid is made by dissolving one pound of nitrate of potash (common nitre or saltpetre), in eight or ten pounds of sulphuric acid (oil of vitriol), or by mixing together sulphuric and nitric acids. This acid dissolves silver easily, while it will not attack copper, iron, lead, gold, or platina.

These properties have rendered it capable of a very useful application in the arts. Among the manufactures at Birmingham, that of making vessels of silver, plated on copper, is a very considerable one. On cutting out the rolled plated metal into pieces of the required form and sizes, there are many shreds, or scraps, as they are called, unfit for any purpose, but the recovery of the metals, by separating them from each other. The easiest and most economical method of parting these two metals, so as not to lose either of them, is an object of some consequence to the manufacturers. For this purpose, two modes were practised; one, by melting the whole of the mixed metals with lead, and separating them by eliquation and testing; and the second, by dissolving both metals in sulphuric acid, with the help of heat, and by separating the sulphate of copper, by dissolving it in water, from the sulphate of silver, which is afterwards to be reduced and purified.

In the first of these methods, there is a considerable waste of lead and copper; and in the second, the quantity of sulphuric acid employed is very great, as much more is dissipated in the form of sulphureous acid than remains in the composition of the two sulphates.

Some years ago, Mr. Keir communicated to an artist the method of effecting the separating of silver and copper, by means of the above-mentioned compound of sulphuric acid and nitre. It is now commonly practised by the manufacturers at Birmingham, and is much more economical, and much easier executed, that any of the above-mentioned methods; for nothing more is necessary than to put the pieces of plated metal into a glazed earthen pan, to pour upon them some of the acid liquor, to stir them about, that the surfaces may be frequently exposed to fresh liquor, and to assist the action by a gentle heat, from 100° to 200° Fahr.

When the liquor is nearly saturated, the silver is to be precipitated from it by common salt, which forms muriate of silver, or luna cornea, easily reducible to a metallic state, by melting in a crucible, with a sufficient quantity of potash; and lastly, by refining the melted silver, if necessary, with a little nitre thrown upon it. In this manner, the silver will be obtained sufficiently pure, and the copper will remain unchanged. Otherwise, the silver may be precipitated in its metallic state, by adding to the solution of silver a few of the pieces of copper, and a sufficient quantity of water to enable the liquor to act upon the copper.

Method of obtaining Gold in a pure State.

Perfectly pure gold may be obtained, by dissolving the gold of commerce in nitro muriatic acid, and precipitating the metal, by adding a weak solution of sulphate of iron. The precipitate, after being well washed and dried, is pure gold.

Method of obtaining Silver in a pure State.

Dissolve the silver of commerce in nitric acid, and add to it some muriatic acid; a white curdy precipitate will be formed, which is muriate of silver. To reduce muriate of silver to the metallic state, let one part of it be mixed with three of soda, and exposed to a white heat. When the mixture is well fused, suffer it to cool; then break the crucible, and separate the pure silver from the muriate of soda which has been formed.

Method of obtaining pure Copper.

Let the copper of commerce be dissolved in muriatic acid, and precipitate it by a polished plate of iron; the precipitate is pure copper.

Of making Brass, and other Alloys of Copper.

Brass is made by fusing together lapis calaminaris (which is an ore of zinc) and copper.

Tombac is formed by melting together twelve parts of copper with three of zinc.

Gun metal consists of nine parts of copper and one of tin.

Bell metal is copper alloyed with one sixth of tin. A smaller proportion of tin is used in making church bells than clock bells, and a little zinc is added for the bells of repeating-watches, and other small bells.

Cock metal is made with copper alloyed with zinc and lead.

The *gold coins* of this country are composed of eleven parts of gold and one of copper.

Standard silver contains fifteen parts of silver and one of copper.

POTTERY.

Pottery, or the art of making vessels of baked earth, is of the remotest antiquity. The ancient Greeks and Etruscans particularly excelled in it. Porcelain, the most perfect of species of pottery, has been made in China from time immemorial.

Alumine and silex are the two substances of which every kind of earthen-ware is made. Clay alone shrinks and cracks; the flint gives it solidity and strength.

Common Pottery, such as coarse brown jugs, &c. are made of the ordinary clays, which are a mixture of sand and clay, coloured by oxide of iron. The clay is well ground, or kneaded, and a lump of it is put upon the centre of a wheel which is kept in motion; then, by means of the workman's hand, or by proper tools, it is formed into the required shape. The pieces are then dried moderately, so as to bear being removed without danger; they are then covered with a glaze, made from semi-vitreous oxide of lead, and put into a furnace, where they are baked. Some sorts are glazed by throwing sea-salt into the furnace among the different pieces of pottery. The salt is decomposed, and the vapours of it form a glazing upon the vessels; but this, though a very simple and ingenious method, does not form a good glazing.

English stone-ware is made of tobacco pipe clay, mixed with flints calcined and ground. This manufacture owes its present state of perfection to that enlightened manufacturer the late Mr. Wedgewood, who spared no pains or expense to improve the art of pottery. He first introduced a superior kind of which he called Queen's ware. The clay of which it is made comes chiefly from the neighbourhood of Corfe Castle in Dorsetshire. It burns extremely white. The pipe clay is much beat in water; by this process the finer parts remain suspended in the water, while the coarser, sand, and other impurities, fall to the bottom. The thick liquid, consisting of water and the finer parts of the clay, is further purified by passing it through hair and lawn sieves, of different degrees of fineness. After this, the liquid is mixed (in various proportions for various wares) with another liquor of the same density, and consisting of flints calcined, ground, and suspended in water. The mixture is then dried in a kiln; and being afterwards beaten to a proper temper, it becomes fit for being formed at the wheel into dishes, plates, bowls, &c. When this ware is to be put into the furnace to be baked, the several pieces of it are placed in cases made of clay, called seggars, which are piled one upon another in the dome of the furnace; a fire is then lighted, and the ware is brought to a proper temper for glazing, and in this state it is called biscuit. Before the glazing takes place it is coloured or painted. Formerly the painting was done by the pencil by hand. It is now commonly effected by taken impressions on paper from engraved copper plates, and transferring them to the earthenware while the ink is wet. The ink is instantly absorbed by the biscuit, and the paper is washed off. The ink for the blue and white ware is made from oxide of cobalt. It is then dipped into a glaze, made by mixing together in water, till it becomes as thick as cream, one hundred and twelve parts of white-lead, twenty-four parts of ground flint, and six parts of ground flint-glass. The ware, by being baked, acquires a strong property of imbibing moisture, and when dipped into the glaze, therefore, it greedily attracts it into its pores, and presently becomes dry. It is then exposed a second time to the fire, by which means the glaze it has imbibed is melted, and a thin glassy coat is formed upon its surface. The colour of the coat is more or less yellow, according as a greater or less proportion of lead has been used. The lead is principally instrumental in producing the glaze, as well as in giving it the yellow colour; for lead, of all the substances hitherto known, has the greatest power of promoting the vitrification of the substances with which it is mixed. The flint serves to give a consistency to the lead during the time of its vitrification, and to hinder it from becoming too fluid, and running down the sides of the ware, and thereby leaving them unglazed.

This glazing, made by means of lead, is liable to be attacked by acids, and is supposed to be productive of deleterious effects, when employed in jars used for pickling, &c.

The following composition has been recommended as a substitute.

To make this, white glass and soda, in equal portions, must be very finely pulverized, carefully sifted, and well mixed. The mixture is then exposed to a strong heat, till it is rendered very dry. It is afterwards put into vessels which have been already baked; it is then melted, and the varnish is made. It may be applied in the same manner as that in common use.

The advantage of it is, that it is safe, and can have none of those poisonous effects which arise from the decomposition of the lead varnish.

A variety of ware has been of late manufactured which the potters call *lustre*. The glazing is formed with platina, or gold. For the first, the platina is dissolved in the nitro-muriatic acid with heat: by adding muriate of ammonia, a yellow precipitate falls down: wash and dry it, grind this powder with a small portion of enamel, in oil of turpentine, and spread it thinly over the glazed surface of the earthen-ware. The ware is now baked in a kiln with a red heat, and the platina will assume the metallic brilliancy.

The gold is managed in the same way.

The *black ware* owes its colour to the oxides of of iron and manganese. It has also less flint, and is more burned; its compactness renders glazing unnecessary.

Porcelain, called also *China,* from being first brought from China, is the most beautiful and perfect species of earthen-ware.

Genuine or true porcelain, is a semi-vitrified earthen-ware, intermediate between common ware and glass. It is infusible in the strongest fire excited in furnaces; it is hard, but not so brittle as glass: it is proof against sudden changes of heat and cold: it is fine grained, and dense without gloss in the fracture, and is translucent. The Chinese long excelled in the art of making porcelain, but it is now made in various parts of Europe of an equally good quality and more ornamental. The Chinese porcelain is said to be composed of two ingredients, one of which is a hard stone called *petuntse,* which is carefully ground to a very fine powder; and the other, called *kaolin,* is a white earthy substance which is intimately mixed with the ground stone.

Several compositions of mingled earths may yield a true porcelain, by being burnt; and the porcelain of various countries differ in their mixtures. But the principal basis of any true porcelain is that kind of clay which becomes white by baking, and which, either by intermingled heterogeneous earth, or by particular additions undergoes in the fire an incipient *vitrification,* in which the true nature of porcelain consists. Feldspar and gypsum, if added, may give that property to infusible clay.

When porcelain is to be made, the clay is properly selected, carefully washed from impurities, and again dried. It is then finely sifted, and most accurately mingled with quartz, ground very fine; to which, then, is added some burnt and finely pulverized gypsum. This mass is worked with water to a paste, and duly kneaded; it is usually suffered to lie in this state for years. The vessels and other goods formed of this mass, are first moderately burnt in earthen pots, to receive a certain degree of compactness, and to be ready for glazing. The glazing consists of an easily melted mixture of some species of earths, as the petrosilex or chert, fragments of porcelain and gypsum, which, when fused together, produce a crystalline, or vitreous mass, that, after cooling, is very finely ground, and suspended in a sufficient quantity of water. Into this fluid the rough ware is dipped, by which the glazing matter is deposited uniformly on every part of its surface. After drying, each article is thoroughly baked or burned in the violent heat of the *porcelain furnace.* It is usual to decorate porcelain by paintings, for which purpose, enamels or pastes, coloured by metallic oxydes, are used, so easy of fusion as to run in a heat less intense than that in which the glazing of the ware melts.

Delft-ware, so called because first made at Delft in Holland, is a kind of pottery made of sand and clay, and but slightly baked, so that it resists sudden application of heat. Articles made of this are glazed with an enamel, composed of common salt, sand ground fine, oxyde of lead, and oxyde of tin. The use of the latter is to give opacity to the glaze.

Tobacco-pipes require a very fine tenacious, and refractory clay, which is either naturally of a perfectly white colour, or, if it have somewhat of a grey cast will necessarily burn white. A clay of this kind must contain no calcareous or ferruginous earth, and must also be carefully deprived of any sand it may contain, by washing. It ought to possess, besides, the capital property of shrinking but little in the fire. If it should not prove sufficiently ductile, it may be meliorated by the admixture of another sort. Last of all, it is beaten, kneaded, ground, washed, and sifted, till it acquires the requisite degree of fineness and ductility.

When, after this preparation, the clay has obtained a due degree of ductility, it is rolled out in small portions to the usual length of a pipe, perforated with a wire, and put together with the wire, into a brass mould rubbed over with oil, to give it its external form; after which it is fixed into a vice, and the hollow part of the head formed with a stopper. The pipes, thus brought into form, are cleared of the redundant clay that adheres to the seams, a rim or border is made round the head, they are then marked with an iron stamp upon the heel, and the surfaces smoothed and polished. When they are well dried, they are put into boxes and baked in a furnace.

In the Dutch manufactories, these boxes consist of conical pots made of clay, with conical lids, with a tube passing through the middle of them, by which the pipes are supported; or else, they are long clay boxes, in which the pipes are laid horizontally, and stratified with fragments of pipes pounded small. Lastly, the pipes, when baked, are covered with a glazing or varnish, and afterwards rubbed with a cloth. This glazing consists of a quarter of a pound of soap, two ounces of white wax, and one ounce of gum arabic, or tragacanth, which are all boiled together in five pints of water, for the space of a few minutes.

MANUFACTURE OF GLASS.

This beautiful material is not of modern invention; it was known to the ancient Romans, but it was by no means common among them; and they do not appear to have had the method of forming it into vessels of various shapes as is practised at present.

Glass is made by fusing together silex and potash, or soda, in proper proportions. Sea sand, which consists almost entirely of quartz and flints reduced to powder, is generally used for this purpose. The alcali is generally procured from the burning of sea weeds; these are cut, dried, and burned in pits dug in the ground; after a sufficient quantity of them have burned in the same pit, a melted or liquid mass is found in the bottom, which, after being well stirred, is suffered to cool; it is then called *kelp*, and consists of a mixture of soda, potash, and parts of half burnt weeds, together with shells, sand, and other impurities.

When the ingredients of which glass is composed are perfectly fused, and have acquired a certain degree of heat, which is known by the fluidity of the mass, part of the melted matter is taken out at the end of a long hollow tube, which is dipped into it, and turned about, till a sufficient quantity is taken up; the workmen then rolls it gently upon a piece of iron, to unite it more intimately. He then blows through the tube, till the melted mass at the extremity swells into a bubble, after which he rolls it again on a smooth surface to polish it, and repeats the blowing, until the glass is brought as near the size and form of the vessel required as he thinks necessary.

If it be a *common bottle*, the melted glass at the end of the tube is put into a mould of the exact size and shape of its body, and the neck is formed on the outside, by drawing out the ductile glass.

If it be a vessel with a *wide orifice*, the glass in its melted state is opened and widened with an iron tool; after which being again heated, it is whirled about with a circular motion, and by means of the centrifugal force thus produced, is extended to the size required. Should a handle, foot, or any thing else of the kind, be required, these are made separately, and stuck on in its melted state.

Window-glass is made in a similar manner, except that the liquid mass at the end of the tube is formed into a cylindrical shape, which being cut longitudinally by scissars or sheers, is gradually bent back until it becomes a flat plate.

Large plate glass, for looking-glasses, &c. is made by suffering the mass in a state of complete fusion to flow upon a table, with iron ledges to confine the melted matter, and as it cools, a metallic roller is passed over it, to reduce it to an uniform thickness. There are various kinds of glass manufactured for different purposes; the principal of these are flint-glass, crown-glass, and bottle-glass.

Flint-glass is the densest, most transparent, colourless, and beautiful. It is sometimes called *crystal.* The best kind is said to be manufactured in London, from 120 parts of white siliceous sand, 40 parts of pearl-ash, 35 of red oxyde of lead, 13 of nitrate of potash, and 25 of black oxyde of manganese. It is the most fusible glass. It is used for bottles, and other utensils, intended to be cut and polished, and for various ornamental purposes.

Crown-glass differs from the last, in containing no lead. It is made of soda and fine sand. It is used for panes of windows, &c.

Bottle-glass is the coarsest sort of all. It is made from kelp and common sand. Its green colour is owing to iron. It is the least fusible.

Glass is sometimes coloured by mixing with it while in a fluid state, various metallic oxyds. It is coloured *blue*, by the oxyd of cobalt; *red*, by the oxyd of gold; *green*, by the oxyd of copper or iron; *yellow*, by the oxyd of silver or antimony, and *violet*, by the oxyd of manganese.

The hardness of glass is very considerable; its specific gravity varies from 2. 3 to 4, according to the quantity of metallic oxyd which enters into its composition. Though glass, when cold, is brittle, it is one of the most ductile bodies known. When liquid, if a thread of melted glass be drawn out, and fastened to a reel, the whole of the glass can be spun off; and by cutting the threads of a certain length, there is obtained a sort of feather of glass. A thread of glass may be thus drawn or spun so fine, as to be scarcely visible to the naked eye. Glass is almost perfectly elastic, and is one of the most sonorous bodies. Fluoric acid dissolves it at common temperatures, and alcalis in a great degree of heat. These are the only substances known which act upon it.

Glass utensils require to be gradually cooled in an oven: this operation is called *annealing*, and is necessary to prevent their breaking by change of temperature, wiping, or slight accidental scratches.

Two toys are made of unannealed glass, which, though commonly used for the amusement of children, exhibit phenomena which justly interest the curiosity of the philosopher; we mean Prince Rupert's drops, and the Bologna flask or philosophical phial.

Prince Rupert's Drops are made by letting drops of melted glass fall into cold water: the drop assumes, by that means, an oval form, with a tail or neck resembling a retort. These drops are said to have been first invented by Prince Rupert, and are, therefore, called by his name. They possess this singular property, that if a small portion of the tail is broken off, the whole bursts into powder with an explosion; and a considerable shock is communicated to the hand that grasps it.

The *Bologna* or *philosophical phial*, is a small vessel of glass, which has been suddenly cooled, open at the upper end, and rounded at the bottom. It is made so thick at the bottom, that it will bear a smart blow against a hard body, without breaking; but if a little pebble, or piece of flint, is let fall into it, it immediately cracks, and the bottom falls into pieces: but unless the pebble or flint is large and angular enough to scratch the surface of the glass, it will not break.

The most generally received explanation of these facts is founded on the assumption, that the dimensions of those bodies which are suddenly cooled, are larger than those which are more gradually cooled. The dimensions, therefore, of the smooth external surface of these glasses which are suddenly cooled, are supposed to be larger than is adapted to the accurate envelopement of the internal part, which is necessarily cooled in a more gradual manner; if, therefore, by a crack or scratch, a disjunction of the cohesion takes place, in the internal surface, the hidden action of the parts which remained in a state of tension, to recover that of perfect cohesion, is supposed to effect the destruction of the the mass.

VARNISHING.

By *varnish* is understood a clear limpid fluid, capable of hardening, without losing its transparency; used by painters, gilders, &c. to give a lustre to their works, and to preserve and defend them from the air and moisture.

A coat of varnish ought to possess the following properties: 1. It must exclude the action of the air: because wood and metals are varnished to defend them from decay and rust. 2. It must resist water; for otherwise the effect of the varnish could not be permanent. 3. It ought not to alter such colours as are intended to be preserved by this means. It is necessary, therefore, that a varnish should be easily extended or spread over the surface, without leaving pores or cavities, that it should not crack or scale, and that it should resist water.

Resins are the only bodies that possess these properties, consequently they must form the basis of every varnish. For this purpose they must be dissolved, as minutely divided as possible, and combined in such a manner, that the imperfections of those that might be disposed to scale, may be corrected by others.

Resins may be dissolved by three agents: 1. by fixed or fat oil; 2. by volatile, or essential oil; 3. by spirit of wine. Accordingly, we have three kinds of varnish: *fat*, or *oily varnish; essential oil varnish;* and *spirit varnish.*

These agents are of such a nature as either to dry up and become hard, or to evaporate and fly off, leaving the resin fixed behind.

Varnishes should be carefully kept from dust, and in very clean vessels: they should be laid as thin and even as possible with a large flat brush, taking care to lay the strokes all one way. A warm room is best for varnishing in, as cold chills the varnish, and prevents it from laying even.

Varnishes are *polished* with pumice-stone and tripoli. The pumice-stone must be reduced to a very fine powder, and put upon a piece of serge moistened with water; with this the varnished substance is to be rubbed equally and lightly. The tripoli must also be reduced to a fine powder, and put upon a clean woollen cloth, moistened with olive-oil, with which the polishing is to be performed. The varnish is then to be wiped with soft linen, and, when quite dry, cleaned with starch, or Spanish-white, and rubbed with the palm of the hand, or with a linen cloth.

Fat Oil Varnish.

Fixed or fat oil will not evaporate; nor will it become dry of itself. To make it dry, it must be boiled with metallic calces or oxides. Litharge is generally used for this purpose. Oil so prepared is called *drying-oil.* To accelerate the drying of oil varnish, oil of turpentine is added.

Gum-copal, and amber, are the substances principally employed in oil varnishes; the copal being whitest, is used for varnishing light, the amber for dark colours.

It is best to dissolve them before mixing them with the oil; because, by this means, they are in less danger of being scorched, and at the same time the varnish is more beautiful. They should be melted in an iron pot over the fire: they are in a proper state for receiving the oil when they give no resistance to the iron spatula, and when they run off from it drop by drop.

To make oil varnish, pour four, six, or eight ounces of drying-oil among sixteen ounces of melted copal, or amber, by little and little, constantly stirring the ingredients at the same time, with the spatula. When the oil is well mixed with the copal or amber, take it off the fire; and when it is pretty cool, pour in sixteen ounces of the essence of Venice turpentine. After the varnish is made, it should be passed through a linen cloth.

Oil varnishes become thick by keeping; but when they are to be used, it is only necessary to pour in a little Venice turpentine, and to put them a little on the fire. Less turpentine is necessary in summer than in the winter: too much oil hinders the varnish from drying; but when too little is used, it cracks, and does not spread properly.

Black Varnish for Coaches and Iron-Work.

This varnish is composed of asphaltum, resin, and amber, melted separately, and afterwards mixed; the oil is then added, and afterwards the turpentine, as directed above. The usual proportions are, twelve ounces of amber, two of resin, two of asphaltum, six of oil, and twelve of turpentine.

A Varnish for rendering Silk Water and Air-tight.

To render the linseed-oil drying, boil it with two ounces of sugar of lead, and three ounces of litharge, for every pint of oil, till the oil has dissolved them; then put a pound of bird-lime, and half a pint of the drying oil into a pot of iron or copper, holding about a gallon; and let it boil gently over a slow charcoal fire, till the bird-lime ceases to crackle; then pour upon it two pints and a half of drying-oil, and boil it for about an hour longer, stirring it often with an iron or wooden spatula. As the varnish in boiling swells much, the pot should be removed from the fire, and replaced when the varnish subsides. While it is boiling, it should be occasionally examined, in order to determine whether it has boiled enough. For this purpose, take some of it upon the blade of a large knife, and after rubbing the blade of another knife upon it, separate the knives; and when, on their separation, the varnish begins to form threads between the two knives, it has boiled enough, and should be removed from the fire. When it is almost cold, add about an equal quantity of spirits of turpentine; mix both well together, and let the mass rest till the next day; then having warmed it a little, strain and bottle it. If it is too thick, add spirits of turpentine. This varnish should be laid upon the stuff when perfectly dry, in a lukewarm state; a thin coat of it upon one side, and, about twelve hours after, two other coats should be laid on, one on each side; and in twenty-four hours the silk may be used.

Mr. Blanchard's Varnish for Air-balloons.

Dissolve elastic gum (Indian-rubber), cut small, in five times its weight of spirits of turpentine, by keeping them some days together; then boil one ounce of this solution in eight ounces of drying linseed-oil for a few minutes, and strain it. Use it warm.

Essential Oil Varnish.

The essential varnishes consist of a solution of resin in oil of turpentine. This varnish being applied, the turpentine evaporates, leaving the resin behind. They are commonly used for pictures.

To dissolve Gum Copal in Oil of Turpentine.

Whatever quantity is to be dissolved should be put into a glass vessel capable of containing at least four times as much, and it should be high in proportion to its breadth.

Reduce two ounces of copal to small pieces, and put them into a proper vessel. Mix a pint of oil of turpentine with one-eighth part of spirit of sal ammoniac; shake them well together, put them to the copal; cork the glass, and tie it over with a string or wire, making a small hole through the cork. Set the glass in a sand heat, so regulated as to make the contents boil as quickly as possible, but so gently, that the bubbles may be counted as they rise from the bottom. The same heat must be kept up exactly till the solution is complete.

It requires the most accurate attention to succeed in this operation. After the spirits are mixed, they should be put to the copal, and the necessary degree of heat be given as soon as possible. It should likewise be kept up with the utmost regularity. If the heat abates, or if the spirits boil quicker than is directed, the solution will immediately stop, and it will afterwards be in vain to proceed with the same materials; but if properly managed, the spirit of sal ammoniac will be seen gradually to descend from the mixture, and attack the copal, which swells and dissolves, except a very small quantity which remains undissolved.

It is of much consequence that the vessel should not be opened till some time after it has been perfectly cold. It has happened, on uncorking the vessel, when it was not warm enough to affect the hand, that the whole of the contents were blown with violence against the ceiling. It is likewise important, that the spirit of turpentine should be of the best quality. The turpentine bought at the colour-shops seldom answers; it should be had from Apothecaries' hall.

This varnish is of a rich deep colour, when viewed in the bottle, but seems to give no colour to the pictures it is laid on. If left in the damp, it remains *tacky*, as it is called, a long time; but if kept in a warm room, or placed in the sun, it dries as well as any other turpentine varnish; and when dry, it appears to be as durable as any other solution of copal.

Spirit Varnishes.

When resins are dissolved in alkohol, commonly called spirits of wine, the varnish dries very speedily, but is subject to crack. This fault is corrected by adding a small quantity of oil of turpentine, which renders it brighter, and less brittle when dry.

To dissolve Gum Copal in Spirits of Wine.

Dissolve half an ounce of camphor in a pint of alkohol, or spirits of wine; put it into a circulating glass, and add four ounces of copal, in small pieces; set it in a sand-heat so regulated, that the bubbles may be counted as they rise from the bottom; and continue the same heat till the solution is completed.

Camphor acts more powerfully upon copal than any other substance. If copal is finely powdered, and a small quantity of dry camphor rubbed with it in the mortar, the whole becomes in a few minutes a tough coherent mass. The process above described will dissolve more copal than the menstruum will retain when cold. The most economical method will, therefore, be, to set the vessel which contains the solution by for a few days; and when it is perfectly settled, pour off the clear varnish, and leave the residuum for a future operation.

This is a very bright solution of copal: it is an excellent varnish for pictures, and may, perhaps, be found to be an improvement in fine japan works, as the stoves used in drying those articles may drive off the camphor entirely, and leave the copal pure and colourless upon the work.

N. B. Copal will dissolve in spirit of turpentine, by the addition of camphor, with the same facility, but not in the same quantity, as in alkohol.

A Varnish for Wainscot, Cane Chairs, &c.

Dissolve in a quart of spirits of wine, eight ounces of gum sandarach, two ounces of seed-lac, and four ounces of resin; then add six ounces of Venice turpentine. If the varnish is to produce a red colour, more of the lac and less of sandarach should be used, and a little dragon's blood should be added. This varnish is very strong.

A Varnish for Toilet-Boxes, Cases, Fans, &c.

Dissolve two ounces of gum mastich, and eight ounces of gum sandarach, in a quart of alkohol; then add four ounces of Venice turpentine.

A Varnish for Violins, and other Musical Instruments.

Put four ounces of gum sandarach, two ounces of lac, two ounces of gum mastich, an ounce of gum elemi, into a quart of alkohol, and hang them over a slow fire till they are dissolved; then add two ounces of turpentine.

Varnish for employing Vermilion for painting Equipages.

Dissolve in a quart of alkohol six ounces of sandarach, three ounces of gum lac, and four ounces of resin; afterwards add six ounces of the cheapest kind of turpentine: mix it with a proper quantity of vermilion when it is to be used.

Seed-lac Varnish.

Take spirits of wine, one quart; put it in a wide mouthed bottle, add thereto eight ounces of seed-lac, that is large grained, bright, and clear, free from dirt and sticks; let it stand two days, or longer, in a warm place, often shaking it. Strain it through a flannel into another bottle, and it is fit for use.

Shell-lac Varnish.

Take one quart of spirits of wine, eight ounces of the thinnest and most transparent shell-lac, which, if melted in the flame of a candle, will draw out in the longest and finest hair; mix and shake these together, and let them stand in a warm place for two days, and it is ready for use. This varnish is softer than that which is made from seed-lac, and, therefore, is not so useful; but may be mixed with it for varnishing wood, &c.

White Varnish for Clock Faces, &c.

Take of spirits of wine, highly rectified, one pint, which divide into four parts; then mix one part with half an ounce of gum mastich, in a phial by itself; one part of spirits, and half an ounce of gum sandarach, in another phial; one part of spirits, and half an ounce of the whitest parts of gum-benjamin. Then mix and temper them to your mind. It would not be amiss to add a little bit of white resin, or clear Venice turpentine, in the mastich bottle; it will assist in giving a gloss. If your varnish prove too strong and thick, add spirits of wine only; if too hard, some dissolved mastich; if too soft, some sandarach or benjamin. No other rule can be given, unless the quality of the gums and the spirits could be ascertained. When you have brought it to a proper temper, warm the silvered plate before the fire, (if a clock face, taking care not to melt the wax,) and with a flat camel's-hair pencil, stroke it all over until no white streaks appear. This will preserve silvering many years.

JAPANNING.

Japanning is properly the art of varnishing and painting ornaments on wood, in the same manner as is done by the natives of Japan in the East Indies.

The substances which admit of being japanned are almost all kinds that are dry and rigid, or not too flexible; as wood, metals, leather, and paper prepared.

Wood and metals do not require any other preparation but to have their surfaces perfectly even and clean; but leather should be securely strained, either on frames or on boards; as its bending, or forming folds, would otherwise crack and force off the coats of varnish. Paper should be treated in the same manner, and have a previous strong coat of some kind of size; but it is rarely made the subject of japanning till it is converted into *papier maché*, or wrought by other means into such form, that its original state, particularly with respect to flexibility, is changed.

One principal variation from the method formerly used in japanning is, the omitting any priming, or undercoat, on the work to be japanned. In the older practice, such a priming was always employed; the use of it was to economize the varnish by filling up the inequalities in the surface. But there is a great inconvenience arising from the use of it, that the japan coats are constantly liable to be cracked and peeled off by any violence, and will not last near so long as the articles which are japanned without any such priming.

The French still retain the use of this undercoat, and their japanned goods are upon that account less durable than those manufactured at Birmingham, where it is not used.

Of the Nature of Japan Grounds.

When a priming is used, the work should first be prepared by being well smoothed with fish-skin or glass-paper, and being made thoroughly clean, should be brushed over once or twice with hot size, diluted with two-thirds water, if it is of the common strength. The priming should then be laid on as even as possible, and should be formed of a size, of a consistency between the common kind and glue, mixed with as much whiting as will give it a sufficient body of colour to hide the surface of whatever it is laid upon, but not more. This must be repeated till the inequalities are completely filled up, and then the work must be cleaned off with Dutch rushes, and polished with a wet rag.

When wood or leather is to be japanned, and no priming is used, the best preparation is to lay two or three coats of coarse varnish, composed in the following manner.

Take of rectified spirits of wine one pint, and of coarse seed-lac and resin, each two ounces; dissolve the seed-lac and resin in the spirit, and then strain off the varnish.

This varnish, as well as all others formed of spirit of wine, must be laid on in a warm place; and if it can be conveniently managed, the piece of work to be varnished should be made warm likewise; and for the same reason, all dampness should be avoided; for either cold or moisture chills this kind of varnish, and prevents its taking proper hold of the substance on which it is laid.

When the work is so prepared, or by the priming with the composition of size and whiting above described, the proper japan ground must be laid on, which is much the best formed of shell-lac varnish, and the colour desired, except white, which requires a peculiar treatment; and if brightness be wanted, then also other means must be pursued.

The colours used with the shell-lac varnish may be any pigments whatever which give the tint of the ground desired.

As metals never require to be under-coated with whiting, they may be treated in the same manner as wood or leather.

White Japan Grounds.

The difficulty of forming a ground that shall be at the same time hard and white, arises from there being no substance that will form a very hard varnish, and yet have no colour. The best is made as follows: Mix flake white, or white lead, with one-sixth of its weight of starch, and dry the mixture, and temper it with mastich varnish. Lay this on the substance to be japanned, with or without the under coat of whiting; then varnish it with five or six coats of a varnish made by dissolving two ounces of picked lac, and three ounces of gum animi, in a a quart of spirit of wine, straining off the clear varnish.

A very good varnish, free from all brittleness, may be formed, by dissolving as much gum animi as the oil will take, in old nut, or poppy oil, boiled gently, when the gum is put into it. The ground of white colour may be laid on in this varnish, and then a coat or two may be put over the ground:

but it must be well diluted with oil of turpentine when it is used.

Blue Japan Grounds.

Blue japan grounds may be formed of bright Prussian-blue; or of verditer, glazed over by Prussian-blue, or smalt. The colour may be best mixed with shell-lac varnish, and brought to a polishing state by five or six coats of varnish of seed-lac; but the varnish, nevertheless, will somewhat injure the colour, by giving to a true blue a cast of green, and fouling in some degree a warm blue by the yellow it contains; where, therefore, a bright blue is required, and a less degree of hardness can be dispensed with, the method before directed in the case of white grounds must be pursued.

Red Japan Grounds.

For a scarlet japan ground, vermilion may be used; but the vermilion has a glaring effect, that renders it much less beautiful than the crimson produced by glazing it over with carmine or fine lake, or even with rose pink, which has a very good effect, used for this purpose. For a very bright crimson, nevertheless, instead of glazing with carmine, the Indian lake should be used, dissolved in the spirit of which the varnish is compounded, which it readily admits of when good; and in this case, instead of glazing with the shell-lac varnish, the upper, or polishing coats need only be used, as they will equally receive and convey the tinge of the Indian lake, which may be actually dissolved by spirits of wine, and this will be found a much cheaper method than the using carmine. If, however, the highest degree of brightness is required, the white varnish must be used.

Yellow Japan Grounds.

For bright yellow grounds, king's yellow, or turpeth mineral should be employed, either alone or mixed with fine Dutch pink, and the effect may be still more heightened, by dissolving powdered turmeric root in the spirits of wine, of which the upper or polishing coat is made; which spirits of wine must be strained from off the dregs, before the seed-lac be added to it, to form the varnish.

The seed-lac varnish is not equally injurious here, and with greens, as is the case of other colours; because, being only tinged with a reddish yellow, it is little more than an addition to the force of the colours.

Yellow grounds may be likewise formed of Dutch pink only, which, when good, will not be wanting in brightness, though extremely cheap.

Green Japan Grounds.

Green grounds may be produced by mixing king's yellow and bright Prussian blue, or rather turpeth-mineral and Prussian blue. And a cheap, but fouler kind by verdigris, with a little of the above mentioned yellows, or Dutch pink. But where a very bright green is wanted, the crystals of verdigris, called distilled verdigris, should be employed; and to heighten the effect, they should be laid on a ground of leaf gold, which renders the colour extremely brilliant and pleasing.

Orange Japan Grounds.

Orange coloured japan grounds may be formed by mixing vermilion, or red lead, with king's yellow, or Dutch pink, or the orange lake, which will make a brighter orange ground than can be produced by any mixture.

Purple Japan Grounds.

These may be produced by the mixture of lake and Prussian blue; or of a darker kind, by vermillion and Prussian blue. They may be treated as the rest, with respect to the varnish.

Black Japan Grounds.

Black grounds may be formed without heat, by either ivory black or lamp black; but the former is preferable where it is perfectly good. These may always be laid on with shell-lac varnish; and have their upper, or polishing coats of common seed-lac varnish, as the tinge or foulness of the varnish can here be no injury.

Common black Japan grounds on iron or copper, produced by means of heat, are formed thus: the piece of work to be japanned must be painted over with drying oil, and a little lamp black; and when it is of a moderate dryness, must be exposed to such a degree of heat, as will change the oil to black, without burning so as to destroy or weaken its tenacity. The stove should not be too hot when the work is put into it, nor the heat increased too fast, either of which errors would make it blister; but the slower the heat is augmented, and the longer it is continued, provided it be restrained within the due degree, the harder will be the coat of japan. This kind of varnish requires no polish, having received, when properly managed, a sufficient one from the heat.

Tortoise-shell Japan Ground.

The best kind is made by means of a varnish prepared in the following manner:

Take of good linseed-oil one gallon, and of umber half a pound; boil them together till the oil become very brown and thick; strain it through a coarse cloth, and boil it in till it acquire the consistence of pitch.

Clean well the metal, or other pieces which are to be japanned, and lay vermilion tempered with shell-lac varnish, or with drying-oil diluted with oil of turpentine, very thinly, on the places intended to imitate the more transparent parts of the tortoise-shell. When the vermilion is dry, brush over the whole with the black varnish, tempered to a true consistence with oil of turpentine; and when it is set and firm, put the work into a stove, where it may undergo a very strong heat, which must be continued a considerable time; if even three weeks or a month it will be the better.

This was given amongst other receipts by Kunckel; but appears to have been neglected till it was revived with great success in the Birmingham manufactures, where it was much used.

Method of painting Japan Work.

Japan work ought properly to be painted with colours in varnish; though, for the greater dispatch, and in some very nice work in small, for the freer use of the pencil, the colours are sometimes tempered in oil; which should previously have a fourth part of its weight of gum animi dissolved in it; or in default of that, gum sandarach, or gum mastich. When the oil is thus used, it should be well diluted with oil of turpentine, that the colours may lay more evenly and thin; by which means, fewer of the polishing or upper coats of varnish become necessary.

In some instances, water colours are laid on grounds of gold, in the manner of other paintings; and are best without any varnish over them. When they are to have the effect of embossed work, the colours for painting are prepared by means of isinglass size, with some honey or sugar candy. The body of which the embossed work is raised, need not, however, be tinged with the exterior colour, but may be formed of very strong gum water, thickened to a proper consistence by bole armoniac and whiting in equal parts; which being laid on the proper figure and repaired when dry, may be then painted with the proper colours, tempered with the isinglass size, or, in the usual manner, with shell-lac varnish.

Manner of varnishing Japan Work.

The finishing of japan-work consists in laying on, and polishing, the outer coats of varnish. This is in general done best with common seed-lac varnish. But where brightness is the most material point, and a tinge of yellow will injure it, seed-lac must give way to the whiter gums; where hardness, and a greater tenacity are most essential, it must be retained; and the mixed varnish mentioned above, under white japanned ground, made of the picked seed-lac, must be adopted.

With respect to making this varnish, it may be observed, that when the spirit of wine is very strong, it will dissolve a greater proportion of the seed-lac; but this quantity will saturate the common, which is seldom of a strength sufficient to make varnishes in perfection. As the chilling, which is the most inconvenient accident attending varnishes of this kind, is prevented, or produced more frequently, according to the strength of the spirit; we shall show a method by which weaker rectified spirits may be rendered of the first degree of strength.

Take a pint of the common rectified spirit of wine, and put it into a bottle, of which it will not fill above three parts; add to it half an ounce of pearl-ashes, salt of tartar, or any other alcaline salt, heated red hot, and powdered as well as it can be without much loss of its heat. Shake the mixture frequently for the space of half an hour; before which time, a great part of the phlegm will be separated from the spirit, and will appear, together with the undissolved part of the salts, in the bottom of the bottle. Let the spirit be poured off or freed from the phlegm and the salts, by means of a separating funnel; and let half an ounce of the pearl-ashes, heated and powdered as before, be added to it, and the same treatment repeated. This may be done a third time, if the quantity of phlegm separated by the addition of the pearl-ashes appear considerable. An ounce of alum reduced to powder, and made hot, but not burnt, must then be put into the spirit, and suffered to remain some hours, the bottle being frequently shaken; after which the spirit being poured off from it, will be fit for use.

The addition of the alum is necessary to neutralize the remains of the alcaline salt, which would otherwise greatly deprave the spirit.

The manner of using the seed-lac, or white varnish, is the same, except with regard to the substance used in polishing; which, where a pure white of a great clearness of other colours is in question, should be itself white; whereas the browner sorts of polishing-dust, as being cheaper, and doing their business with greater dispatch, may be used in other cases. The pieces of work to be varnished should be placed near a fire, or in a room where there is a stove, and made perfectly dry; and then the varnish may be rubbed over them by the proper brushes made for that purpose, beginning in the middle, and passing the brush to one end, and then with another stroke from the middle, passing it to the other. But no part should be crossed, or twice passed over, in forming one coat, where it can be possibly avoided. When one coat is dry, another must be laid over it; and this must be continued at least five or six times, or more, if, on trial, there be not sufficient thickness of varnish to bear the polish, without laying bare the painting or ground colour underneath.

When a sufficient number of coats is thus laid on, the work is fit to be polished; which must be done, in common cases, by rubbing it with a rag, dipped in tripoli, or rotten-stone, finely powdered; but, towards the end of the rubbing, a little oil of any kind should be used along with the powder; and when the work appears sufficiently bright and glossy, it should be well rubbed with the oil alone, to clean it from the powder, and give it a still brighter lustre.

In case of white grounds, instead of tripoli, or rotten-stone, fine putty, or whiting must be used; both of which should be washed over, to prevent the danger of damaging the work, from any sand or gritty matter that may happen to be mixed with them.

It is a great improvement in all kinds of japanned work, to harden the varnish by means of heat; which in every degree that it can be applied, short of what would burn or calcine the matter, tends to give it a more firm and strong texture.

Where metal forms the body, a very hot stove may be used; and the pieces of work may be continued in it a considerable time, especially if the heat be gradually increased; but where wood is in question, heat must be sparingly used, as it would otherwise warp or shrink the body, so as to injure the general figure.

LACQUERING.

Lacquering is the laying either coloured or transparent varnishes on metals, in order to produce the appearance of a different colour in the metal, or to preserve it from rust, or the injuries of the weather.

Lacquering is used where brass is to be made to have the appearance of being gilt; where tin is wanted to have the resemblance of yellow metals; and where brass locks or nails, or other such matters, are to be defended from the corrosion of the air or moisture.

The principal substance used for the composition of lacquers, is seed-lac; but for coarser purposes, resin or turpentine is added, in order to make the lacquer cheaper.

A Lacquer for Brass, to imitate Gilding.

Take of turmeric one ounce, and of saffron and Spanish annotto, each two drachms. Put them into a proper bottle, with a pint of highly rectified spirits of wine, and place them in a moderate heat, often shaking them for several days. A very strong yellow tincture will then be obtained, which must be strained off from the dregs through a coarse linen cloth; and then, being put back into the bottle, three ounces of good seed-lac, powdered grossly, must be added, and the mixture placed again in a moderate heat and shaken till the seed-lac be dissolved, or at least such a part of it as may. The lacquer must then be strained, and must be put into a bottle well corked.

Where it is desired to have the lacquer warmer or redder than this composition, the proportion of the annotto must be increased; and where it is wanted cooler, or nearer to a true yellow, it must be diminished.

The above, properly managed, is an extremely good lacquer, and of moderate price; but the following, which is cheaper, and may be made where the Spanish annotto cannot be procured good, is not greatly inferior to it.

Take of turmeric root, ground, one ounce, of the best dragon's blood half a drachm. Put them to a pint of spirits of wine, and proceed as above. By diminishing the proportion of dragon's blood, the varnish may be rendered of a redder or truer yellow cast.

Saffron is sometimes used to form the body of colour in this kind of lacquer, instead of the turmeric; but though it makes a warmer yellow, yet the dearness of it, and the advantage which turmeric has in forming a much stronger tinge in spirits of wine, gives it the preference. Though being a true yellow, and consequently not sufficiently warm to overcome the greenish cast of brass, it requires the addition of some orange coloured tinge to make it a perfect lacquer.

Aloes and gamboge are also sometimes used in lacquers for brass; but the aloes is not necessary where turmeric or saffron is used; and the gamboge, though a very strong milky juice in water, affords but a very weak tinge in spirit of wine.

A Lacquer for Tin, to imitate a Yellow Metal.

Take of turmeric root one ounce, of dragon's blood two drachms, and of spirits of wine one pint; add a sufficient quantity of seed-lac.

A Lacquer for Locks, &c.

Seed-lac varnish alone, or with a little dragon's blood: or a compound varnish of equal parts of seed-lac and resin, with or without the dragon's blood.

A Gold-coloured Lacquer for gilding Leather.

What is called *gilt leather*, and used for screens, borders for rooms, &c. is only leather covered with *silver* leaf, and lacquered with the following composition.

Take of fine white resin four pounds and a half, of common resin the same quantity, of gum sandarach two pounds and a half, and of aloes two pounds; mix them together, after having bruised those which are in great pieces, and put them into an earthen pot, over a good fire made of charcoal, or over any fire where there is no flame. Melt all the ingredients in this manner, stirring them well with a spatula, that they may be thoroughly mixed together, and be prevented also from sticking to the bottom of the pot. When they are perfectly melted and mixed, and gradually to them seven pints of linseed oil, and stir the whole well together with the spatula. Make the whole boil, stirring it all the time to prevent a kind of sediment that will form, from sticking to the bottom of the vessel. When the varnish is almost sufficiently boiled, add gradually half an ounce of litharge, or half an ounce of red-lead, and when they are dissolved, pass the varnish through a linen cloth, or flannel bag.

The time of boiling this varnish should be about seven or eight hours. This, however, varies, according to circumstances. The way of knowing when it is sufficiently boiled, is by taking a little on some instrument, and if it draws out and is ropy, and sticks to the fingers, drying on them, it is done; but if not, it must be boiled till it acquires these qualities.

GILDING.

Gilding is the application of gold to the surfaces of bodies: it is of two principal kinds, according to the method of applying the gold.

Wood, leather, paper, and similar substances, are gilt by fastening on leaves of gold by means of some cement. But metals are gilt by a chemical application of the gold to the surface. This last is called *water gilding*.

The gilding of wood, and similar substances, is of three kinds; *oil gilding*, *burnished gilding*, and *japanners' gilding*, which we shall severally describe, after noticing the materials and tools necessary for going to work.

Of Gold-Leaf.

There are three kinds of gold-leaf in common use.

Pure gold-leaf, which is made by hammering gold between the leaves of a book made of skins, till they are sufficiently thin.

Pale leaf-gold, which has a greenish colour, and is made of gold alloyed with silver.

Dutch gold, which is brought from Holland, and is in fact only copper-leaf coloured by the fumes of zinc. It is much cheaper than true leaf-gold, and is very useful where large quantities of gilding are wanted, which can be defended from the weather, and where great nicety is not required; but it changes its colour entirely when exposed to moisture; and, indeed, in all cases, its beauty is soon impaired, unless well secured by varnish. It is therefore only a cheap substitute for true gold-leaf, which may be useful where durability is not an object.

Of the Instruments necessary for Gilding.

The first instrument is the *cushion*, for receiving the leaves of gold from the books in which they are bought. It is made by covering a board of about eight inches square, with a double thickness of flannel, and over that, a piece of buff leather, and fastening it tight round the edges.

The *knife* for cutting the leaves into the requisite sizes should be made like a pallet knife, and should not have its edge too sharp.

The *tip* is a tool made by fastening the long hairs of a squirrel's tail between two cards, and is used for taking up the gold-leaf after it is cut, and applying it to the article to be gilded.

A *fitch pencil* is used for the same purpose as the last, in taking up very small bits of gold-leaf. A *ball of cotton* is necessary for pressing down the leaf, after it is laid on. A large *camel's-hair brush* is used for dusting the work, and clearing away the superfluous gold.

Oil Gilding.

Prime the work with boiled linseed-oil and white-lead; and when that is dry, do it over with a thin coat of gold size, made of stone ochre ground in fat oil. When that is so dry as to feel clammy to the fingers, or to be, as the gilders call it, *tacky*, it is fit for gilding. Having spread your leaves upon the cushion, cut them into slips of the proper width for covering the work. Then breathe upon your tip, which, by moistening it, will cause it to take up the leaves from the cushion. Having ap-applied them by the tip on the proper parts of the work, press them down by the ball of cotton. Observe to repair, by putting small pieces of gold on any parts which you have omitted to cover. When all the work is sufficiently covered, let it dry, and clean it off with the brush.

This sort of gilding is the easiest, least expensive, and stands the weather best, and may be cleaned with a little water at any time; but wants the lustre of burnished gilding.

Burnished Gilding.

This is the sort of gilding generally used for picture-frames, looking-glasses, &c.

The wood intended to be gilt in this manner should first be well sized, and then done over with seven or eight coats of size and whiting, so as to cover it with a body of considerable thickness. Having got a sufficient quantity of whiting upon the work, it must be carefully cleaned off, taking care to free all the cavities and hollows from the whiting that may have choked them up, and by proper moulds and tools restoring the sharpness of the mouldings intended to be shown.

It is then to receive a coat of size, which is made by boiling armeniac bole with parchment size. This must also remain till it is sufficiently dry for the gold. It must not be quite dry; therefore it would not be prudent to lay on more at a time, than can be gilt before it becomes too dry.

The work being thus prepared, place it a little declining from you, and having a cup of clean water ready and some hair pencils, moisten a part of the work, and then apply the gold by the tip to the moistened part. The gold will immediately adhere close to the work: proceed to wet the next part, and apply the gold as before, repeating this operation till the whole is completed; taking care not to let any drops of water come upon any part of the gold already laid on. Care should therefore be taken, that no part be missed in going over it at first, as it is not so easily mended as the oil gilding.

The work being thus gilt, it is suffered to remain about twenty-four hours; when the parts that are designed to be burnished are polished with a dog's tooth, or, what is better, with an agate burnisher. The gilding must not be quite dry when it is burnished; there is a state proper for the purpose, which is only to be known by experience.

Japanners' Gilding.

The gilding of japanned work consists in drawing with a hair pencil, in gold size, the intended ornaments, and afterwards applying gold leaf or gold powder.

The gold size may be prepared in the following manner: take of linseed-oil, and of gum animi, four ounces. Set the oil to boil in a proper vessel, and then add the gum animi gradually in powder, stirring each quantity about in the oil, till it appear to be dissolved, and then putting in another, till the whole be mixed with the oil. Let the mixture continue to boil, till, on taking a small quantity out, it appear of a thicker consistence than tar, and then strain the whole through a coarse cloth, and keep it for use; but it must, when applied, be mixed with vermilion and oil of turpentine.

Having laid on the gold size, and suffered it to dry, the gold leaf is applied in the usual way, or if it is not wanted to shine so much, gold powder is applied, which is made by grinding gold leaf upon a stone with honey, and afterwards washing the honey away with water. If the gilding is to be varnished over, Dutch gold may be used, or aurum musivum may be used instead of real gold powder.

To write on Paper with Letters of Gold.

Put some gum arabic into common writing ink, and write with it in the usual way. When the writing is dry, breathe on it; the warmth and moisture softens the gum, and will cause it to fasten on the gold leaf, which may be laid on in the usual way, and the superfluous part brushed off. Or instead of this, any japanners' size may be used.

To lay Gold upon White Earthen-Ware, or Glass.

Procure some japanners' gold size, and with it draw your design upon the vessel to be gilt, moistening the gold size, as you find necessary, with oil of turpentine. Set your work in a clean place to dry, for about an hour, and then place it so near the fire that you could but just bear the heat of it with your hand for a few seconds. Let it remain there till it feels quite tacky or clammy, then, having procured a cushion, and some leaf gold, cut it into slips of the proper size, and lay it on with a little cotton wool. When the gold is all on, put the ware into an oven to be baked for two or three hours.

Glasses, &c. may also be gilt by drawing the figures with shell gold mixed with gum arabic and a little borax. Then apply sufficient heat to it; and, lastly, burnish it.

Gilding on Glass or Porcelain, by Burning-in.

Dissolve gold in aqua regia, and evaporate the acid by heat; a gold powder will be obtained; or precipitate the gold from the solution by pieces of copper. Lay this gold on with a strong solution of borax and gum water, and it will be ready for burning-in.

Gilding Metals.

One method of applying gold upon metals is by first cleaning the metal to be gilt; then gold leaf is laid on it, which, by means of rubbing with a polished blood stone, and a certain degree of heat, are made to adhere. In this manner silver leaf is fixed and burnished upon brass, in the making of what is called *French plate;* and sometimes also gold leaf is burnished upon copper and iron.

Gilding by Amalgamation is by previously forming the gold into a paste, or amalgam, with mercury.

In order to obtain an amalgam of gold and mercury, the gold is first to be reduced into thin plates or grains, which are heated red-hot, and thrown into mercury previously heated, till it begins to smoke. Upon stirring the mercury with an iron rod, the gold totally disappears. The proportion of mercury to gold is generally as six or eight to one.

The method of gilding by amalgamation is chiefly used for gilding copper, or an alloy of copper with a small portion of zinc, which more readily receives the amalgam, and is also preferable, on account of its colour, which more resembles that of gold than the colour of copper.

When the metal to be gilt is wrought or chased, it ought to be previously covered with quick-silver before the amalgam is applied, that this may be easier spread; but when the surface of the metal is plain, the amalgam may be directly applied to it.

The metal required to be gilt is first rubbed over with a little aqua-fortis, by which the surface is cleaned from any rust or tarnish that might prevent the union of the two metals. The amalgam, being then equally spread over the surface by means of a brush, the mercury is evaporated by a heat just sufficient for that purpose; for if it be too great, part of the gold may also be expelled, and part of it will run together, and leave some of the surface of the metal bare. While the mercury is evaporating, the piece is to be from time to time taken from the fire, that it may be examined; that the amalgam may be spread more equally by means of a brush; that any defective parts of it may be again covered, and that the heat may not be too suddenly applied to it. When the mercury is evaporated, which is known by the surface becoming entirely of a dull yellow colour, the metal must then undergo other operations, by which the fine gold colour is given to it.

First, the gilded piece of metal is rubbed with a *scratch-brush* (which is a brush composed of brass-wire,) till its surface is made smooth; then it is covered over with a composition called *gilding wax*, and is again exposed to the fire till the wax be burnt off. This wax is composed of bees-wax, sometimes mixed with some of the following substances, red ochre, verdigris, copper scales, alum, vitriol, borax; but according to Dr. Lewis, the saline substances are sufficient, without any wax.

By this operation the colour of the gilding is heightened; and this effect seems to be produced by a perfect dissipation of some mercury remaining after the former operation.

The gilt surface is then covered over with a saline composition, consisting of nitre, alum, or other vitriolic salt, ground together, and mixed up into a paste with water or urine. The piece of metal thus covered is exposed to a certain degree of heat, and then quenched in water. By this method its colour is further improved, and brought nearer to that of gold. This effect seems to be produced by the acid of nitre (which is disengaged by the sulphuric acid of the alum, during the exposure to heat) acting upon any particles of copper which may happen to lie upon the gilded surface.

Lastly, some artists think that they give an additional lustre to their gilt work, by dipping it in a liquor prepared by boiling some yellow materials, as sulphur, orpiment, or turmeric. The only advantage of this operation is, that part of the yellow matter remains in some of the hollows of the carved work, in which the gilding is apt to be more imperfect, and to which it gives a rich and solid appearance.

It may here be noticed, that the use of the aquafortis or nitrous acid, mentioned in the beginning of the process, is not, as is generally supposed, confined merely to cleansing the surface of the metal to be gilt from rust or tarnish; but it also greatly facilitates the application of the amalgam to the surface of that metal, probably in the following manner: It first dissolves part of the mercury of the amalgam; and when this solution is applied to the copper, this latter metal having a stronger disposition to unite with the nitrous acid than the mercury has, precipitates the mercury upon its surface, in the same manner as a polished piece of iron precipitates upon its surface copper from a solution of blue vitriol. When the metal to be gilt is thus covered over with a thin coat of precipitated mercury, it readily receives the amalgam.

On the subject of gilding by amalgamation, Dr. Lewis has the following remarks: "There are two principal inconveniencies in this business; one, that the workmen are exposed to the fumes of the mercury, and generally, sooner or later, have their health greatly impaired by them: the other, the loss of the mercury; for though part of it is said to be detained in the cavities made in the chimneys for that purpose, yet the greatest part of it is lost. From some trials I have made, it appeared that both these inconveniencies, particularly the first and most considerable one, might be in a good measure avoided, by means of a furnace of a due construction."

If the communication of a furnace with its chimney, instead of being over the fire, is made under the grate, the ash-pit door, or other apertures beneath the grate, closed, and the mouth of the furnace left open, the current of air, which otherwise would have entered beneath, enters now at the top, and passing down through the grate to the chimney, carries with it completely both the vapour of the fuel, and the fumes of such matters as are placed upon it. The back part of the furnace should be raised a little higher above the fire than the fore part, and an iron plate laid over it, that the air may enter only at the front where the workman stands, who will be thus effectually secured from the fumes, and from being incommoded by the heat, and at the same time have full liberty of introducing, inspecting, and removing the work.

If such a furnace is made of strong forged (not milled) iron plate, it will be sufficiently durable. The upper end of the chimney may reach above a foot and a half higher than the level of the fire; over this is to be placed a larger tube, leaving an interval of an inch, or more, all round between it and the chimney, and reaching to the height of ten or twelve feet; the higher the better. The external air, passing up between the chimney and the outer pipe, prevents the latter from being much heated, so that the mercurial fumes will condense against its sides into running quicksilver, which falling down to the bottom, is there catched in a hollow rim, formed by turning inwards a portion of the lower part, and conveyed by a pipe at one side into a proper receiver.

Gilding Iron or Steel.—In gilding iron or steel by means of an amalgam, as the metal has no affinity for the mercury, an agent must be employed to dispose the surface to receive the gilding. For this purpose, a solution of mercury in nitrous acid (aqua fortis,) or what the workmen call quicksilver water, is applied to the parts intended to be gilded; the acid, by a stronger affinity, seizes on a portion of the iron, and deposits in the place of it a thin coating of mercury, which will not refuse a union afterwards with the gold amalgam that may be applied; but, by this process, the surface of the metal is injured by the nitrous acid, and the union of the mercury is very slight, so that a bright and durable gilding cannot be obtained.

Another method.—Sometimes a solution of *blue vitriol* is applied, with a camel's hair pencil, to the parts of the steel intended to be gilt. By a chemical action, exactly similar to what we have described as taking place when a solution of nitrate of mercury is employed, a thin coating of copper is precipitated on the metal. Copper having an affinity for mercury, a kind of union may by this means be effected between the amalgam and the iron or steel, as the case may be. In whichever of these ways the amalgam be brought into union with the steel, the surface is injured by the action of the acid employed, and still a heat sufficient to volatilize the mercury, must be afterwards used.

Gilding of Iron by heat.—When the surface is polished bright, it must be heated till it becomes blue. Gold leaf is then applied to its surface, and burnished down. It is then heated again, and another layer of gold burnished on it. In this manner three or four coats are given, according to the strength of the gilding intended. This is a more laborious process than the two last, but it is not attended with so much risk.

An improved process for gilding Iron or Steel.—This process, which is less known among artists than it deserves to be, may prove useful to those who have occasion to gild iron or steel. The first part of the process consists in pouring over a solution of gold in nitro-muriatic acid (aqua regia) about twice as much ether, which must be done with caution, and in a large vessel. These liquids must then be shaken together; as soon as the mixture is at rest, the ether will be seen to separate itself from the nitro-muriatic acid, and to float on the surface. The nitro-muriatic acid becomes more transparent, and the ether darker than they were before; the reason of which is, that the ether has taken the gold from the acid. The whole mixture is then to be poured into a glass funnel, the lower aperture of which is small; but this aperture must not be opened till the fluids have compleely separated themselves from each other. It is then to be opened; by which means the liquid which has taken the lowest place by its greater gravity, viz. the nitro-muriatic acid will run off; after which, the aperture is to be shut, and tha funnel will then be found to contain nothing but ether mixed wlth the gold, which is to be put into well-closed bottles, and preserved for use. In order to gild iron or steel, the metal must first be well polished with the finest emery, or rather with the finest crocus martis, or colcothar of vitriol, and common brandy. The auriferous ether is then to be applied with a small brush; the ether soon evaporates, and the gold remains on the surface of the metal. The metal may then be put into the fire, and afterwards polished. By means of this auriferous ether, all kinds of figures may be delineated on iron, by employing a pen, or fine brush. It is in this manner, probably, that the Sohlinger sabre blades are gilded.

Instead of ether, the essential oils may be used; such as oil of turpentine, or oil of lavender, which will also take gold from its solution.

Cold Gilding of Silver.—Dissolve gold in the nitro-muriatic acid, and dip some linen rags in the solution; then burn them, and carefully preserve the ashes, which will be very black, and heavier than common. When any thing is to be gilded, it must be previously well burnished; a piece of cork is then to be dipped, first into a solution of salt in water, and afterwards into the black powder; and the piece, after being rubbed with it, must be burnished. This powder is frequently used for gilding delicate articles of silver.

Gilding of Brass or Copper.—Fine instruments of brass, in order that their surface may be kept longer clean, may be gilded in the following manner.

Provide a saturated solution of gold, and having evaporated it to the consistence of oil, suffer it to shoot into crystals. These crystals must then be dissolved in pure water, and the articles to be gilded being immersed in it, are then to be washed in pure water, and afterwards burnished. This process may be repeated several times, till the articles have been well gilt. A solution of gold crystals is preferred to a mere solution of gold; because, in the latter, there is always a portion of free acid, which will not fail to exercise more or less action on the surface of the brass or copper, and injure its polish.

Grecian Gilding.—Dissolve some mercury in muriatic acid (spirits of salts), which will give a muriate of mercury. Mix equal parts of this and sal ammoniac, and dissolve them in aqua fortis. Put some gold into this, and it will dissolve. When this is applied to silver, it becomes black; but by heating, it assumes the appearance of gilding.

To make Shell-Gold.

Grind up gold-leaf with honey, in a mortar; then wash away the honey with water, and mix the gold-powder with gum-water. This may be applied to any article with a camel's-hair pencil, in the same way as any other colour.

SILVERING,

Wood, paper, &c. are silvered in the same manner as gilding is performed, using only silver instead of gold-leaf.

To Silver Copper or Brass.

Cleanse the metal with aqua fortis, by washing it lightly, and then throwing it into the water; or by scouring it with salt and tartar with a wire-brush. Dissolve some silver in aqua fortis, and put pieces of copper into the solution; this will throw down the silver in a state of metallic powder. Take fifteen or twenty grains of this silver powder, and mix with it two drachms of tartar, the same quantity of common salt, and half a drachm of alum; rub the articles with this composition till they are perfectly white, then brush it off, and polish them with leather.

Another method.—Precipitate silver from its solution in aqua fortis by copper, as before; to half an ounce of this silver add common salt and sal ammoniac, of each two ounces, and one drachm of corrosive sublimate; rub them together, and make them into a paste with water. With this, copper utensils of every kind, that have been previously boiled with tartar and alum, are rubbed; after which they are made red hot and polished.

To Silver the Dial-plates of Clocks, Scales of Barometers, &c.

Take half an ounce of silver lace, add thereto an ounce of double refined aqua fortis; put them into an earthen pot, and place them over a gentle fire till all is dissolved, which will happen in about five minutes; then take them off, and mix it in a pint of clear water; after which, pour it into another clean vessel, to free it from grit or sediment; then add a spoonful of common salt, and the acid, which has now a green tinge, will immediately let go the silver particles, which form themselves into a white curd; pour off the acid, and mix the curd with two ounces of salt of tartar, half an ounce of whiting, and a large spoonful of salt, more or less, according as you find it for strength. Mix it well up together, and it is ready for use.

Having well cleared the brass from scratches, rub it over with a piece of old hat and rotten-stone, to clear it from all greasiness, and then rub it with salt and water with your hand: take a little of the before-mentioned composition on your finger, and rub it over where the salt has touched, and it will adhere to the brass and completely silver it. After which, wash it well with water, to take off what aqua fortis may remain in the composition; when dry, rub it with clean rag, and give it one or two coats of varnish, prepared according to the directions given under the article *varnishes.*

This silvering is not durable, but may be improved by heating the article, and repeating the operation till the covering seems sufficiently thick.

Silver Plating.

The coat of silver applied to the surface of the copper by the means mentioned above, is very thin, and is not durable. A more substantial method of doing it, is as follows: form small pieces of silver and copper, and tie them together with wire, putting a little borax between. The proportion of silver may be to that of the copper as one to twelve. Put them into a white heat, when the silver will be firmly fixed to the copper. The whole is now made to pass between rollers, till it is of the required thickness for manufacturing various articles.

To make French Plate.

Heat the copper articles intended to be plated, and burnish silver-leaf on it, with a burnisher.

To make Shell Silver.

Grind up leaf-silver with gum-water or honey; when you have ground it, wash away the gum or honey, and use the powder that remains with gum-water, or glaire of eggs. This is laid on with a hair-pencil.

To silver Looking Glasses.

The following apparatus must first be prepared.

1. A square marble slab, or smooth stone, well polished, and ground flat; the larger the better; with a frame round it, or a groove cut in its edges, to keep the superfluous mercury from running off.
2. Lead weights, covered with cloth, to keep them from scratching the glass; from one pound weight to twelve pounds each, according to the size of the glass which is laid down.
3. Rolls of tinfoil.
4. Quicksilver.

Cut the tinfoil a little larger than the glass every way, and lay it flat upon the stone; and with a straight piece of hard wood, about three inches long, stroke it every way, that there be no crease or wrinkles in it; then drop a little mercury upon it, and with a piece of cotton, wool, or hair's foot, spread it all over the foil, so that every part may be touched with the mercury. Then, keeping the marble slab nearly level with the horizon, pour the mercury over the foil; cover it with a fine paper; and lay two weights very near its lowest end or side, to keep the glass steady, while you draw the paper from between the silvered foil and the glass, which must be laid upon the paper. As you draw the paper, you must take care that no air bubbles be left; for they will always appear, if left in at the first. You must likewise be sure to make the glass as clean as possible on the side intended to be silvered, and have the paper also quite clean; otherwise, when you have drawn the paper from under it, dull white streaks will appear, which are very disagreeable.

After the paper is drawn out, place as many weights upon the glass as you conveniently can, in order to press out the superfluous mercury, and make the foil adhere to the glass. When it has lain six or seven hours in this situation, raise the stone about two or three inches at its highest end, that as much of the mercury may run off as possible; let it remain two days before you venture to take it up. But before you take the weights off, gently brush the edges of the glass, that no mercury may adhere to them; then take it up, and turn it directly over, with its face side downward; but raise it by degrees, that the mercury may not drip off too suddenly: for if, when taken up, it is immediately set perpendicular, air will get in between the foil and the glass at the top, as the mercury descends to the bottom; by which means, if you be not exceedingly careful, your labour will be lost.

Another method, is to slide the glass over the foil, without the assistance of paper.

To Silver Glass Globes.

Take half an ounce of clean lead, and melt it with an equal weight of pure tin; then immediately add half an ounce of bismuth, and carefully skim off the dross; remove the mixture from the fire, and, before it grows cold, add five ounces of mercury, and stir the whole well together; then put the fluid amalgam into a clean glass, and it is fit for use.

When this amalgam is used for foiling or silvering, let it first be strained through a linen rag; then gently pour some ounces of it into the globe intended to be foiled: the mixture should be poured into the globe, by means of a glass or paper-funnel, reaching almost to the bottom of the globe, to prevent its splashing to the sides; the globe should then be dexterously inclined every way, though very slowly, in order to fasten the silvering. When this is once done, let the globe rest some hours; repeat the operation, till at length the fluid mass is spread even, and fixed over the whole internal surface, as it may be known to be, by viewing the globe against the light; the superfluous amalgam may then be poured out, and the outside of the globe cleared.

To Silver the Convex Side of Glasses for Mirrors.

Take an earthen plate, on which pour some prepared plaster of Paris, mixed with water, of a proper consistence; then immediately, before it grows too stiff, lay the glass, with its convex side downward, in the middle of the plate, and press it until it lies quite close to the plaster; in which situation let it remain until the plaster becomes quite dry. After which, work a groove with your finger, round the outside of the glass, in order to let the superfluous mercury rest upon it; then cut the tinfoil to a proper size, and press it with the glass into the plaster-mould, in order to make it lie close; after which, cover it with the mercury, and, without a paper (as directed for silvering plain mirrors), slide it over the silvered foil; then place a weight on it, and let it stand two or three days, rising it by degrees, that the mercury may drip off gradually.

After this method common window-glass, &c. may be silvered.

To lay Paper Prints on the Inside of Glass Globes.

First, cut off all the white part of your impression, so that nothing appear but the print; then prepare some strong gum arabic water, or size, with which you must brush over the face side; after which put it into the globe, and with a long small stick, on which a camel's-hair pencil is fixed, stick it even on; and by this method you may put what number of prints you please into the globe. Let them dry about twelve hours; then pour some prepared plaster of Paris, either white or tinged, whatsoever colour you please, and turn the globe easily about, so that every part be covered; pour out the superfluous plaster, and it is finished.

TINNING.

Tinning is the art of covering any metal with a thin coating of tin. Copper and iron are the metals most commonly tinned. The use of tinning these metals is to prevent them from being corroded by rust, as tin is not so easily acted upon by the air or water as iron and copper are.

What are commonly called tin-plates, or sheets, so much used for utensils of various kinds, are in fact iron-plates coated with tin.

The principal circumstance in the art of tinning, is to have the surfaces of the metal to be tinned perfectly clean and free from rust, and also that the melted tin be perfectly metallic, and not covered with any ashes or calx of tin.

Tinning of Iron.

When iron-plates are to be tinned, they are first scoured, and then put into what is called a pickle, which is oil of vitriol diluted with water; this dissolves the rust or oxyd that was left after scouring, and renders the surface perfectly clean. They are then again washed and scoured. They are now dipped into a vessel full of melted tin, the surface of which is covered with fat or oil, to defend it from the action of the air. By this means, the iron coming into contact with the melted tin in a perfectly metallic state, it comes out completely coated.

When a small quantity of iron only is to be tinned, it is heated, and the tin rubbed on with a piece of cloth, or some tow, having first sprinkled the iron with some powdered resin, the use of which is to reduce the tin that may be oxydated. Any inflammable substance, as oil, for instance, will have in some degree, the same effect; which is owing to their attraction for oxygen.

The Tinning of Copper.

Sheets of copper may be tinned in the same manner as iron. Copper boilers, saucepans, and other kitchen utensils, are tinned after they are made. They are first scoured; then made hot; and the tin rubbed on, as before, with resin. Nothing ought to be used for this purpose but pure grain-tin; but lead is frequently mixed with the tin, both to adulterate its quality, and make it lay on more easily; but it is a very pernicious practice, and ought to be severely reprobated.

To whiten Brass or Copper by boiling.

Put the brass or copper into a pipkin with some white tartar, alum, and grain-tin, and boil them together. The articles will soon become covered with a coating of tin, which, when well polished, will look like silver. It is in this manner that pins, and many sorts of buttons, are whitened.

BRONZING.

Bronzing is colouring plaster, or other busts and figures, with metallic powders, in order to make them appear as if made of copper or other metals. The powders used for this purpose are either fine copper-filings, aurum musivum, or copper precipitated from its solution in aqua fortis by iron. Having done over the substance to be bronzed with a dark green colour, the projecting parts are touched with either isinglass size, japanners' gold size, or, in some cases, with drying-oil, or oil-paint; the powders are then rubbed on, taking care that the projecting parts receive more of the powder than the cavities, to imitate the brightness on those parts of bronze which are liable to be rubbed.

SOLDERING.

Soldering is the art of joining two pieces of metal together, by heating them with a thin piece or plate of metal interposed between them. Thus tin is a solder for lead; brass, gold, or silver, are solders for iron, &c.

To make Silver Solder.

Melt fine silver two parts, brass one part; do not keep them long in fusion, lest the brass fly off in fumes.

Another for coarser Silver.

Melt four parts of fine silver, and three of brass; throw in a little borax, and pour it out as soon as it is melted.

A Solder for Gold.

Melt copper one part, fine silver one part, and gold two parts; add a little borax when it is just melted, then pour it out immediately.

The Method of soldering Gold or Silver.

After the solder is cast into an ingot, it would be more ready for use if your were to draw it into small wire, or flat it between two rollers; after that cut it into little bits; then join your work together with fine soft iron-wire; and with a camel's-hair pencil, dipt in borax finely powdered and well moistened with water, touch the joint intended to be soldered; placing a little solder upon the joint, apply it upon a large piece of charcoal, and, with a blow-pipe and lamp, blow upon it the flame until it melts the solder.

To cleanse Silver or Gold after it is soldered.

Make the silver red hot, and let it cool; then boil it in alum-water, in an earthen vessel, and it will be as clean as when new. If gold, boil it in urine and sal ammoniac.

A Solder for Lead.

Put two parts lead to one part tin: its goodness is tried by melting it, and pouring the size of a crown-piece upon the table; if it be good, there will arise little bright stars in it. Apply resin when you use this solder.

A Solder for Tin.

Take four parts of pewter, one of tin, and one of bismuth; melt them together, and run them into narrow thin lengths.

A Solder for Iron.

Nothing here is necessary, but good tough brass, with borax applied, mixed with water to the consistence of paste.

MOULDING AND CASTING.

The art of taking casts or impressions from pieces of sculpture, medals, &c. is of very great importance in the fine arts.

In order to procure a copy or cast from any figure, bust, medal, &c. it is necessary to obtain a mould by pressing upon the thing to be moulded or copied, some substance which, when soft, is capable of being forced into all the cavities or hollows of the sculpture. When this mould is dry and hard, some substance is poured into it, which will fill all the cavities of the mould, and represent the form of the original from which the mould was taken.

The particular manner of moulding depends upon the form of the subject to be worked upon. When there are no projecting parts but such as form a right or a greater angle with the principal surface of the body, nothing more is required than to cover it over with the substance of which the mould is to be formed, taking care to press it well into all the cavities of the original, and to take it off clean, and without bending.

The substances used for moulding are various, according to the nature and situation of the sculpture. If it may be laid horizontally, and will bear to be oiled without injury, plaster of Paris may be advantageously employed; which may be poured over it to a convenient thickness, after oiling it, to prevent the plaster from sticking. A composition of bees-wax, resin, and pitch, may also be used; which will be a very desirable mould, if many casts are to be taken from it. But if the situation of the sculpture be perpendicular, so that nothing can be poured upon it, then clay, or some similar substance, must be used. The best kind of clay for this purpose is that used by the sculptors for making their models with; it must be worked to a due consistence, and having spread it out to a size sufficient to cover all the surface, it must be sprinkled over with whiting, to prevent it from adhering to the original. Bees-wax and dough, or the crumb of new bread, may also be used for moulding some small subjects.

When there are under cuttings in the bas relief, they must be first filled up before it can be moulded, otherwise the mould could not be got off. When the casts are taken afterwards, these places must be worked out with a proper tool.

When the model, or original subject, is of a round form, or projects so much that it cannot be moulded in this manner, the mould must be divided into several parts; and it is frequently necessary to cast several parts separately, and afterwards to join them together. In this case, the plaster must be tempered with water to such a consistence, that it may be worked like soft paste, and must be laid on with some convenient instrument, compressing it so as to make it adapt itself to all parts of the surface. When the model is so covered to a convenient thickness, the whole must be left at rest till the plaster is set and firm, so as to bear dividing without falling to pieces, or being liable to be put out of its form by any slight violence; and it must then be divided into pieces, in order to its being taken off from the model, by cutting it with a knife with a very thin blade; and being divided, must be cautiously taken off, and kept till dry: but it must be observed, before the separation of the parts be made, to notch them across the joints, or lines of division, at proper distances, that they may with ease and certainty be properly put together again. The art of properly dividing the moulds, in order to make them separate from the model, requires more dexterity and skill than any other thing in the art of casting, and does not admit of rules for the most advantageous conduct of it in every case. Where the subject is of a round or spheroidal form, it is best to divide the mould into three parts, which will then easily come off from the model; and the same will hold good of a cylinder, or any regular curve figure.

The mould being thus formed and dry, and the parts put together, it must be first oiled, and placed in such a position that the hollow may lie upwards, and then filled with plaster mixed with water; and when the cast is perfectly set and dry, it must be taken out of the mould, and repaired when necessary, which finishes the operation.

In larger masses, where there would otherwise be a great thickness of the plaster, a core may be put within the mould, in order to produce a hollow in the cast, which both saves the expense of the plaster, and renders the cast lighter.

In the same manner, figures, busts, &c. may be cast of lead, or any other metal in the moulds of plaster or clay; taking care, however, that the moulds be perfectly dry; for should there be any moisture, the sudden heat of the metal would convert it into vapour, which would produce an explosion by its expansion, and blow the melted metal about.

To take a Cast in Metal from any small Animal, Insect, or Vegetable.

Prepare a box of four boards, sufficiently large to hold the animal, in which it must be suspended by a string; and the legs, wings, &c. of the animal, or the tendrils, leaves, &c. of the vegetable, must be separated, and adjusted in their right position by a pair of small pincers. A due quantity of plaster of Paris, mixed with talc, must be tempered to the proper consistence with water, and the sides of the box oiled. Also a straight piece of stick must be put to the principal part of the body, and pieces of wire to the extremities of the other parts, in order that they may form, when drawn out after the matter of the mould is set and firm, proper channels for pouring in the metal, and vents for the air; which otherwise, by the rarefaction it would undergo from the heat of the metals, would blow it out, or burst the mould. In a short time the plaster will set, and become hard; when the stick and wires may be drawn out, and the frame or coffin in which the mould was cast taken away; and the mould must then be put, first, into a moderate heat, and, afterwards, when it is as dry as can be rendered by that degree, removed into a greater, which may be gradually increased, till the whole be red hot. The animal or vegetable inclosed in the mould will then be burnt to a coal; and may be totally calcined to ashes, by blowing for some time into the charcoal and passages made for pouring in the metal, and giving vent to the air, which will at the same time that it destroys the remainder of the animal or vegetable matter, blow out the ashes. The mould must then be suffered to cool gently, and will be perfect; the destruction of the substance included in it having produced a corresponding hollow; but it may nevertheless be proper to shake the mould, and turn it upside down, as also to blow with the bellows into each of the air-vents, in order to free it wholly from any remainder of the ashes; or, where there may be an opportunity of filling the hollow with quicksilver, it will be found a very effectual method of clearing the cavity, as all dust, ashes, or small detached bodies, will necessarily rise to the surface of the quicksilver, and be poured out with it. The mould being thus prepared, it must be heated very hot when used, if the cast is to be made with copper or brass, but a less degree will serve for lead or tin. The metal, being poured into the mould, must be gently struck, and then suffered to rest till it be cold; at which time it must be carefully taken from the cast, but without force; for such parts of the matter as appear to adhere more strongly must be softened, by soaking in water till they be entirely loosened, that none of the more delicate parts of the cast may be broken off or bent.

When talc cannot be obtained, plaster alone may be used; but it is apt to be calcined by the heat used in burning the animal or vegetable from whence the cast is taken, and to become of too incoherent and friable a texture. Stourbridge, or any other good clay, washed perfectly fine, and mixed with an equal part of fine sand, may be employed. Pounded pumice-stone, and plaster of Paris, in equal quantities, mixed with washed clay in the same proportion, is said to make excellent moulds.

Method of taking a Cast in Plaster from a Person's Face.

The person whose likeness is required in plaster must lie on his back, and the hair must be tied up so that none of it covers the face. Into each nostril convey a conical piece of stiff paper open at both ends, to allow of breathing. The face is then lightly oiled over in every part with salad-oil, to prevent the plaster from sticking to the skin. Procure some fresh burnt plaster, and mix it with water to a proper consistence for pouring. Then pour it by spoonfuls quickly all over the face (taking care the eyes are shut), till it is entirely covered to the thickness of a quarter of an inch. This substance will grow sensibly hot, and in a few minutes will be hard. This being taken off will form a mould, in which a head of clay may be moulded, and therein the eyes may be opened, and such other additions and corrections may be made as are necessary. Then, this second face being anointed with oil, a second mould of plaster must be made upon it, consisting of two parts joined lengthwise along the ridge of the nose; and in this a cast in plaster may be taken, which will be exactly like the original.

To take Casts from Medals.

In order to take copies of medals, a mould must first be made; this is generally either of plaster of Paris, or of melted sulphur.

After having oiled the surface of the medal with a little cotton, or a camel's hair pencil dipped in oil of olives, put a hoop of paper round it, standing up above the surface of the thickness you wish the mould to be. Then take some plaster of Paris, mix it with water to the consistence of cream, and with a brush rub it over the surface of the medal, to prevent air-holes from appearing; then immediately afterwards make it to a sufficient thickness, by pouring on more plaster. Let it stand about half an hour, and it will in that time grow so hard, that you may safely take it off; then pare it smooth on the back and round the edges neatly. It should be dried, if in cold or damp weather, before a brisk fire. If you cover the face of the mould with fine plaster, a coarser sort will do for the back: but no more plaster should be mixed up at one time than can be used, as it will soon get hard, and cannot be softened without burning over again.

Sulphur must not be poured upon silver medals, as this will tarnish them.

To prepare this mould for casting sulphur or plaster of Paris in, take half a pint of boiled linseed oil, and oil of turpentine one ounce, and mix them together in a bottle; when wanted, pour the mixture into a plate or saucer, and dip the surface of the mould into it; take the mould out again, and when it has sucked in the oil, dip it again. Repeat this till the oil begins to stagnate upon it; then take a little cotton wool, hard rolled up, to prevent the oil from sticking to it, and wipe it carefully off. Lay it in a dry place for a day or two (if longer the better,) and the mould will acquire a very hard surface from the effect of the oil.

To cast plaster of Paris in this mould, proceed with it in the same manner as above directed for obtaining the mould itself, first oiling the mould with olive oil. If sulphur casts are required, it must be melted in an iron ladle.

Another method with Isinglass.—Dissolve isinglass in water over the fire; then, with a hair pencil, lay the melted isinglass over the medal: and when you have covered it properly, let it dry.

When it is hard, raise the isinglass up with the point of a penknife, and it will fly off like horn, having a sharp impression of the medal.

The isinglass may be made of any colour by mixing the colour with it; or you may breathe on the concave side, and lay gold leaf on it, which, by shining through, will make it appear like a gold medal. But if you wish to imitate a copper medal, mix a little carmine with the isinglass, and lay gold leaf on as before.

CEMENTS.

Cements require to be of various compositions, according to the substances to which they are applied, and whether they are to be exposed to heat and moisture.

Common Glue.

Common glue is formed by extracting by boiling the gelatinous part of cuttings or scraps of coarse leather, or the hides of beasts. It is then poured out in thin cakes and dried.

Isinglass Glue.

Isinglass glue is made by dissolving beaten isinglass in water by boiling, and, having strained it through a coarse linen cloth, evaporating it again, o such a consistence, that being cold, the glue will be perfectly hard and dry.

This cement is improved by dissolving the isinglass in any proof spirit by heat, or by adding to it when dissolved in water, an equal quantity of spirits of wine.

It is still further improved by adding to the isinglass, previous to its solution in spirits, one-third of its weight of gum ammoniac. Expose the mixture to a boiling heat, until the isinglass and gum are dissolved, and until a drop of the composition become stiff instantly as it cools. It will at any future time melt with a degree of heat little exceeding that of the human body, and, in consequence of so soon becoming stiff on cooling, forms a very valuable cement for many purposes, particularly for the very nice and delicate one of fixing on the antennæ, legs, &c. of insects in cabinets of natural history. The easy melting of this cement is no objection to its use in cases where the articles themselves may afterwards be exposed to moderate heat; for it owes this property only to the presence of the spirit which evaporates soon after it has been applied. When used to join broken glass or china, the pieces to be joined should be previously warmed. Immersion in hot water will give them a sufficient degree of heat. Wipe off the water before applying the cement, which may be laid on with a pencil; then press the pieces together, binding them with a string, or bit of soft wire, if necessary.

This isinglass glue is far preferable to common glue for nice purposes, being much stronger, and less liable to be softened either by heat or moisture.

Parchment Glue.

Take one pound of shreds of parchment, or vellum, and boil it in six quarts of water till the quantity be reduced to one quart; strain off the fluid from the dregs, and then boil it again till it be of the consistence of glue.

The same may be done with glovers' cuttings of leather, which are dressed with alum instead of being tanned; this will make a colourless glue.

A good Glue for Sign-Boards, or any thing that must stand the Weather.

Melt common glue with water to a proper consistence; then add one eighth of boiled linseed oil, dropping it into the glue gently, and stirring it all the time.

A very strong glue is made by adding some powdered chalk to common glue.

Another that will resist water is made by adding half a pound of common glue to two quarts of skimmed milk.

Preparation of Lip Glue, for cementing Paper, Silk, thin Leather, &c.

Take of isinglass glue and parchment glue, each one ounce; of sugar-candy, and gum tragacanth, each two drachms; add to them an ounce of water, and boil the whole together, till the mixture appears, when cold, of the proper consistence of glue. Then form it into small rolls, or any other figure that may be most convenient.

This glue may be wet with the tongue, and rubbed on the edges of the paper, silk, &c. that are to be cemented, which will, on their being laid together, and suffered to dry, unite as firmly as any other part of the substance.

Lapland Glue.

The bows of the Laplanders are composed of two pieces of wood glued together; one of them of birch, which is flexible, and the other of fir of the marshes, which is stiff, in order that the bow when bent may not break, and that when unbent it may not bend. When these two pieces of wood are bent, all the points of contact endeavour to disunite themselves, and to prevent this, the Laplanders employ the following cement: they take the skins of the largest perches*, and having dried them, moisten them in cold water until they are so soft that they may be freed from the scales, which they throw away. They then put four or five of these skins into a rein-deer's bladder, or they wrap them up in the soft bark of the birch-tree, in such a manner that water cannot touch them, and place them thus covered into a pot of boiling water, with a stone above them to keep them at the bottom. When they have boiled about an hour, they take them from the bladder or bark, and they are then found to be soft and viscous. In this state they employ them for glueing together the two pieces of their bows, which they strongly compress and tie up till the glue is well dried. These pieces never afterwards separate.

A Glue from Cheese.

Take skimmed-milk cheese, free it from the rind, cut it into slices, and boil it in water, stirring it with a spoon until it be reduced to a strong glue, which does not incorporate with water. Then throw away the hot water; pour cold water over the glue, and knead it afterward in warm water, subjecting it to the same process several times. Put the warm glue on a grinding-stone, and knead it with quick-lime until you have a good glue. When you wish to use this glue you must warm it; if it be employed cold it is not so strong, but it may also be used in that manner. This glue is insoluble in water as soon as it is dry, and it becomes so in forty-eight hours after it has been applied. It may be used for glueing wood, and for cementing marble and broken stone and earthen-ware. Baits for catching fish may also be made of it. Fish are very fond of it, and it resists water.

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* It is probable that eel-skins would answer the same purpose.

Jewellers' Cement.

In setting precious stones, pieces are sometimes broken off by accident. In such cases, they often join the pieces so correctly, that an inexperienced eye cannot discover the stone to have been broken. They employ for this purpose a small piece of gum mastich applied between the fragments, which are previously heated sufficiently to enable them to melt the interposed gum. They are then pressed together, to force out the redundant quantity of gum.

Turkey Cement, for joining Metals, Glass, &c.

Dissolve five or six bits of mastich, as large as peas, in as much spirits of wine as will suffice to render it liquid; in another vessel dissolve as much isinglass (which has been previously soaked in water till it is swollen and soft,) in brandy or rum, as will make two ounces by measure of strong glue, and add two small bits of gum galbanum, or ammoniacum, which must be rubbed or ground till they are dissolved; then mix the whole with a sufficient heat; keep it in a phial stopt, and when it is to be used set it in hot water.

A Cement for broken China, Glasses, &c.

Take quick-lime and white of eggs, or old thick varnish; grind and temper them well together.

Drying oil and white lead are also frequently used for cementing china and earthen-ware; but this cement requires a long time to dry. Where it is not necessary the vessels should endure heat or moisture, isinglass glue, with a little tripoli, or chalk, is better. The juice of garlic also forms a strong cement, and the joining can scarcely be perceived.

A Cement for Chemical Glasses that will bear the Fire.

Mix equal quantities of wheat flour, fine powdered Venice glass, pulverized chalk, with half the quantity of fine brick dust, and a little scraped lint in the whites of eggs: this mixture is to be spread upon a linen cloth, and applied to the crack of the glasses, and should be well dried before they are put into the fire.

A Cement useful for Turners.

Take resin, one pound; pitch, four ounces: melt these together, and, while boiling hot, add brick-dust, until, by dropping a little upon a stone, you perceive it hard enough; then pour it into water, and immediately make it up in rolls, and it is fit for use.

Another, finer.—Take resin, one ouuce; pitch, two ounces; add red ochre, finely powdered, until you perceive it strong enough. Sometimes a small quantity of tallow is used, according to the heat of the weather, more being necessary in winter than in summer.

Either of these cements is of excellent use for turners. By applying it to the side of a chuck, and making it warm before the fire, you may fasten any thin piece of wood, which will hold while you turn it; when you want it off again, strike it on the top with your tool, and it will drop off immediately.

A strong Cement for Electrical Purposes.

Melt one pound of resin in a pot or pan, over a slow fire; add to it as much plaster of Paris, in fine powder, as will make it hard enough, then add a spoonful of linseed-oil, stirring it all the while, and try if it be hard and tough enough for your purpose; if it is not sufficiently hard, add more plaster of Paris; and if not tough enough, a little more linseed-oil.

This is a very good cement for fixing the necks of globes or cylinders of electrical machines, or any thing else that requires to be strongly fixed.

Another, softer.—Take resin, one pound; bees-wax, one ounce; add to it as much red-ochre as will make it of sufficient stiffness; pour it into water, and make it into rolls. This cement is useful for cementing hoops on glasses, or any other mounting of electrical apparatus.

A Cement for Glass-Grinders.

Take pitch, and boil it; add to it sifted-wood ashes, and keep stirring it all the while, until you have it of a proper temper: the addition of a little tallow may be added, as you find necessary.

Another, for small work.—To four ounces of resin add one-fourth of an ounce of bees-wax, and four ounces of whiting, made previously red hot and melt them together. The whiting should be put in while hot, that it may not have time to imbibe moisture from the atmosphere.

Shell-lac is a very strong cement for holding metals, glass, or precious stones, while cutting, turning, or grinding them. The metal, &c. should be warmed, to melt it. For fastening ruby cylinders in watches, and similar delicate purposes, shell-lac is excellent.

To solder or cement broken Glass.

Broken glass may be soldered or cemented in such a manner as to be as strong as ever, by interposing between the parts, glass ground up like a pigment, but of easier fusion than the pieces to be joined, and then exposing them to such a heat as will fuse the cementing ingredient, and make the pieces agglutinate without being themselves fused.

A glass for the purpose of cementing broken pieces of flint glass, may be made by fusing some of the same kind of glass previously reduced to powder, along with a little red-lead and borax, or with the borax only.

Cement for Derbyshire Spar and other Stones.

A cement for this purpose may be made with about seven or eight parts of resin and one of bees-wax, melted together with a small quantity of plaster of Paris. If it is wished to make the cement fill up the place of any small chips that may have been lost, the quantity of plaster must be increased a little. When the ingredients are well mixed, and the whole is nearly cold, the mass should be well kneaded together. The pieces of spar that are to be joined must be heated until they will melt the cement, and then pressed together, some of the cement being previously interposed.

Melted sulphur applied to fragments of stones previously heated by placing them before a fire, to at least the melting point of sulphur, and then joined with the sulphur between, makes a pretty firm and durable joining.

Little deficiencies in the stone, as chips out of corners, &c. may also be filled up with melted sulphur, in which some of the powder of the stone has been melted.

A Cement that will stand against boiling Water, and even bear a considerable Pressure of Steam.

In joining the flanches of iron cylinders, and other parts of hydraulic and steam engines, great inconvenience is often experienced from the want of a durable cement.

Boiled linseed-oil, litharge, red and white lead, mixed together to a proper consistence, and applied on each side of a piece of flannel previously shaped to fit the joint, and then interposed between the pieces before they are brought home (as the workmen term it) to their place by the screws or other fastenings employed, make a close and durable joint.

The quantities of the ingredients may be varied without inconvenience, only taking care not to make the mass too thin with oil. It is difficult in many cases instantly to make a good fitting of large pieces of iron work, which renders it necessary sometimes to join and separate the pieces repeatedly, before a proper adjustment is obtained. When this is expected, the white-lead ought to predominate in the mixture, as it dries much slower than the red. A workman, knowing this fact, can be at little loss in exercising his own discretion in regulating the quantities. It is safest to err on the side of the white-lead, as the durability of the cement is no way injured thereby, only a longer time is required for it to dry and harden.

When the fittings will not admit easily of so thick a substance as flannel being interposed, linen may be substituted, or even paper or thin pasteboard.

This cement answers well also for joining broken stones, however large. Cisterns built of square stones, put together with this cement, will never leak or want any repairs. In this case the stones need not be entirely bedded in it: an inch, or even less, of the edges that are to lie next the water, need only be so treated; the rest of the joint may be filled with good lime.

Another Cement that will stand the Action of Boiling Water and Steam.

This cement, which is preferable even to the former for steam-engines, is prepared as follows.

Take two ounces of sal ammoniac, one ounce of flowers of sulphur, and sixteen ounces of cast iron filings or borings. Mix all well together by rubbing them in a mortar, and keep the powder dry.

When the cement is wanted for use, take one part of the above powder and twenty parts of clean iron borings or filings, and blend them intimately by grinding them in a mortar. Wet the compound with water, and when brought to a convenient consistence, apply it to the joints with a wooden or blunt iron spatula.

By a play of affinities, which those who are at all acquainted with chemistry will be at no loss to comprehend, a degree of action and re-action takes place among the ingredients, and between them and the iron surfaces, which at last causes the whole to unite as one mass. In fact, after a time, the mixture and the surfaces of the flanches become a species of pyrites, holding a very large proportion of iron, all the parts of which cohere strongly together.

Blood Cement.

A cement often used by copper-smiths to lay over the rivets and edges of the sheets of copper in large boilers, to serve as an additional security to the joinings, and to secure cocks, &c. from leaking, is made by mixing pounded quick-lime with ox's blood. It must be applied fresh made, as it soon gets hard.

We believe if the properties of this cement were duly investigated, it would be found useful for many purposes to which it has never yet been applied. It is extremely cheap, and very durable.

Flour Paste.

Flour paste for cementing is formed principally of wheaten flour boiled in water till it be of a glutinous or viscid consistence.

It may be prepared of these ingredients simply for common purposes, but when it is used by bookbinders, or for paper hangings, it is usual to mix with the flour a fifth or sixth of its weight of powdered alum; and where it is wanted still more tenacious, gum arabic, or any kind of size, may be added.

Japanese Cement, or Rice Glue.

This elegant cement is made by mixing rice flour intimately with cold water, and then gently boiling it. It is beautifully white, and dries almost transparent. Papers pasted together by means of this cement will sooner separate in their own substance than at the joining, which makes it extremely useful in the preparation of curious paper articles, as tea trays, ladies' dressing boxes, and other articles which require layers of paper to be cemented together. It is in every respect preferable to common paste made with wheat flour, for almost every purpose to which that article is usually applied. It answers well in particular, for pasting into books the copies of writings taken off by copying machines on unsized silver paper.

With this composition, made with a small quantity of water, that it may have a consistence similar to plastic clay, models, busts, statues, basso relievos, and the like, may be formed. When dry, the articles made of it are susceptible of a high polish; they are also very durable.

The Japanese make quadrille fish of this substance, which so nearly resemble those made of mother of pearl, that the officers of our East Indiamen are often imposed upon.

Of Sizes.

Common size is manufactured in the same manner, and generally by the same people, as glue. It is indeed glue left in a moister state, by discontinuing the evaporation before it is brought to a dry consistence, and, therefore, further particulars respecting the manufacture of it are needless here.

Isinglass size may also be prepared in the manner above directed for the glue, by increasing the proportion of the water for dissolving it. And the same holds good of parchment size.

LUTES.

In many chemical operations the vessels must be covered with something to preserve them from the violence of the fire, from being broken or melted, and also to close exactly their joinings to each other, in order to retain the substances which they contain, when they are volatile and reduced to vapour.

The coating used for retorts, &c. to defend them from the action of the fire, is usually composed of nearly equal parts of coarse sand and refractory clay. These matters ought to be well mixed with water and a little hair, so as to form a liquid paste, with which the vessels are covered layer upon layer, till it is of the required thickness. The sand, mixed with the clay, is necessary to prevent the cracks which are occasioned by the contracting of the clay during its drying, which it always does when pure. The hair serves also to bind the parts of the lute, and to keep it applied to the vessel; for, notwithstanding the sand which is introduced into it, some cracks are always formed, which would occasion pieces of it to fall off.

The lutes with which the joinings of vessels are closed are of different kinds, according to the nature of the operations to be made, and of the substances to be distilled in these vessels.

When vapours of watery liquors, and such as are not corrosive, are to be contained, it is sufficient to surround the joining of the receiver to the nose of the alembic, or of the retort, with slips of paper, or linen, covered with flour paste. In such cases, also, slips of wet bladder are very conveniently used.

When more penetrating and dissolving vapours are to be contained, a lute is to be employed of quick-lime slacked in air, and beaten into a liquid paste with whites of eggs. This paste is to be spread upon linen slips, which are to be applied exactly to the joining of the vessels. This lute is very convenient, easily dries, becomes solid, and sufficiently firm.

Lastly, when saline acids, and corrosive vapours are to be contained, we must then have recourse to the lute called fat lute. This lute is made by forming into a paste some dried clay, finely powdered, sifted through a silken search, and moistened with water; and then, by beating this paste well in a mortar, with boiled linseed oil, that is, oil which has been rendered dry by litharge dissolved in it, this lute easily takes and retains the form given to it. It is generally rolled into cylinders of a convenient size. These are to be applied, by flattening them to the joinings of the vessels, which ought to be perfectly dry; because the least moisture would prevent the lute from adhering. When the joinings are closed with this fat lute, the whole is to be covered with slips of linen, spread with lute of lime and whites of eggs. These slips are to be fastened with packthread. The second lute is necessary to keep on the fat lute, because the latter remains soft, and does not become solid enough to stick on alone.

INK-MAKING.

Inks are fluid compounds, intended to form characters, or some other kinds of figures, on proper grounds of paper, parchment, or such other substance as may be fit to receive them.

There are two principal kinds of ink, writing and printing ink.

Writing Ink.

When to an infusion of gall-nuts some solution of sulphate of iron (green copperas) is added, a very dark blue precipitate takes place. This precipitate is the gallic acid of the galls united to the iron of the green vitriol, forming *gallat of iron*, which is the basis of writing ink. If galls and sulphate of iron only were used, the precipitate would fall down, leaving the water colourless; and, in order to keep it suspended in the water, forming a permanently black, or rather very dark blue fluid, gum arabic is added, which, by its viscid nature, prevents the precipitate from falling down.

Various receipts have been given for the composition of writing ink, but very few have been founded upon a knowledge of its real nature. Though so important an article, it is but lately that it has been studied with any attention; and even still, the principles and theory of its formation do not appear to be so thoroughly understood as might be wished. The receipt given by M. Ribancourt is as follows: Take eight ounces of Aleppo galls, in coarse powder; four ounces of logwood, in thin chips; four ounces of sulphate of iron (green copperas); three ounces of gum arabic, in powder; one ounce of sulphate of copper (blue vitriol); and one ounce of sugar-candy. Boil the galls and logwood together in twelve pounds of water for one hour, or till half the liquid has been evaporated. Strain the decoction through a hair sieve, or linen cloth, and then add the other ingredients. Stir the mixture till the whole is dissolved, more especially the gum; after which, leave it to subside for twenty-four hours. Then decant the ink, and preserve it in bottles of glass or stone-ware, well corked.

Red writing ink is made in the following manner: Take of the raspings of Brazil wood a quarter of a pound, and infuse them two or three days in vinegar. Boil the infusion for an hour over a gentle fire, and afterwards filter it while hot. Put it again over the fire, and dissolve in it, first, half an ounce of gum arabic, and afterwards of alum and white sugar, each half an ounce.

Printing Ink.

Printers' ink is a black paint composed of lamp-black and linseed or suet oil boiled, so as to acquire considerable consistence and tenacity. The art of preparing it is kept a secret; but the obtaining good lamp-black appears to be the chief difficulty in making it.

The ink used by copper-plate printers, differs from the last only in the oil not being so much boiled, and the black which is used being Frankfort black.

Sympathetic Inks.

Sympathetic inks are such as do not appear immediately after they are written with, but which may be made to appear at pleasure, by certain means. A variety of substances have been used for this purpose. We shall describe the best of them.

1. Dissolve some sugar of lead in water, and write with the solution. When dry, no writing will be visible. When you want to make it appear, wet the paper with a solution of alcaline sulphuret (liver of sulphur), and the letters will immediately appear of a brown colour. Even exposing the writing to the vapours of these solutions will render it apparent.

2. Write with a solution of gold in aqua regia, and let the paper dry gently in the shade. Nothing

will be seen; but draw a sponge over it, wetted with a solution of tin in aqua regia; the writing will immediately appear of a purple colour.

3. Write with an infusion of galls, and when you wish the writing to appear, dip it into a solution of green vitriol; the letters will be black.

4. Write with diluted sulphuric acid, and nothing will be visible. To render it so, hold it to the fire, and the letters will instantly appear black.

5. Juice of lemons, or onions, a solution of sal ammoniac, green vitriol, &c. will answer the same purpose, though not so easily, or with so little heat.

6. Green sympathetic ink. Dissolve cobalt in nitro muriatic acid, and write with the solution. The letters will be invisible till held to the fire, when they will appear green, and will disappear completely again when removed into the cold. In this manner they may be made to appear and disappear at pleasure.

A very pleasant experiment of this kind is to make a drawing representing a winter scene, in which the trees appear void of leaves, and to put the leaves on with this sympathetic ink; then, upon holding the drawing near to the fire, the leaves will begin to appear in all the verdure of spring, and will very much surprise those who are not in the secret.

7. Blue sympathetic ink. Dissolve cobalt in nitric acid; precipitate the cobalt by potash; dissolve this precipitated oxyd of cobalt in acetic acid, and add to the solution one-eighth of common salt.

This will form a sympathetic ink, that, when cold, will be invisible, but will appear blue by heat.

REMOVING STAINS.

To remove Ink Stains.

The stains of ink on cloth, paper, or wood, may be removed by almost all acids; but those acids are to be preferred which are least likely to injure the texture of the stained substance. The muriatic acid, diluted with five or six times its weight of water, may be applied to the spot, and, after a minute or two, may be washed off, repeating the application as often as may be found necessary. But the vegetable acids are attended with less risk, and are equally effectual. A solution of the oxalic, citric (acid of lemons), or tartareous acids, in water, may be applied to the most delicate fabrics without any danger of injuring them; and the same solutions will discharge writing, but not printing ink. Hence they may be employed in cleaning books which have been defaced by writing on the margin, without impairing the text. Lemon-juice, and the juice of sorrels, will also remove ink stains, but not so easily as the concrete acid of lemons, or citric acid.

To remove Iron Stains.

These may be occasioned either by ink stains, which, on the application of the soap, are changed into iron stains, or by the direct contact of rusted iron. They may be removed by diluted muriatic acid, or by one of the vegetable acids, already mentioned. When suffered to remain long on cloth, they become extremely difficult to take out, because the iron, by repeated moistening with water, and exposure to the air, acquires such an addition of oxygen, as renders it insoluble in acids. It has been found, however, that even these spots may be discharged, by applying first a solution of an alcaline sulphuret, which must be well washed from the cloth, and afterwards a liquid acid. The sulphuret, in this case, extracts part of the oxygen from the iron, and renders it soluble in diluted acids.

To remove the Stains of Fruit and Wine.

These are best removed by a watery solution of the oxygenated muriatic acid, or by that of oxygenated muriate of potash or lime, to which a little sulphuric acid has been added. The stained spots may be steeped in one of these solutions till it is discharged; but the solution can only be applied with safety to white goods, because the uncombined oxygenated acid discharges all printed and dyed colours. A convenient mode of applying the oxygenated acid, easily practicable by persons who have not the apparatus for saturating water with the gas, is as follows: Put about a table-spoonful of muriatic acid (spirit of salt) into a tea-cup, and add to it about a tea-spoonful of powdered manganese; then set this cup in a larger one filled with hot water; moisten the stained spot with water, and expose it to the fumes that arise from the tea-cup. If the exposure be continued a sufficient length of time, the stain will disappear.

To remove Spots of Grease from Cloth.

Spots of grease may be removed by a diluted solution of potash; but this must be cautiously applied, to prevent injury to the cloth. Stains of white wax, which sometimes fall upon the clothes from wax candles, are removable by spirits of turpentine, or sulphuric ether. The marks of white paint may also be discharged by the last-mentioned agents.

To take Spots of Grease out of Books, Prints, or Paper.

After having gently warmed the paper that is stained with grease, wax, oil, or any other fat body, take out as much as possible of it by means of blotting paper; then dip a small brush in the essential oil of turpentine, heated almost to ebullition (for when cold it acts only very weakly), and draw it gently over both sides of the paper, which must be carefully kept warm. This operation must be repeated as many times as the quantity of the fat body imbibed by the paper, or the thickness of the paper, may render necessary. When the greasy substance is entirely removed, recourse may be had to the following method to restore the paper to its former whiteness, which is not completely restored by the first process. Dip another brush in highly rectified spirit of wine, and draw it in like manner over the place which was stained, and particularly round the edges, to remove the border that would still present a stain. By employing these means with proper caution, the spot will totally disappear, the paper will resume its original whiteness, and if the process has been employed on a part written on with common ink, or printed with printer's ink, it will experience no alteration.

OF STAINING WOOD.

To stain Wood Yellow.

Take any white wood, and brush it over several times with the tincture of turmeric root, made by putting an ounce of turmeric, ground to powder, to a pint of spirit, and after they have stood for some days, straining off the tincture. If the yellow colour be desired to have a reddish cast, a little dragon's blood must be added.

A cheaper, but less strong and bright yellow, is, by the tincture of French berries made boiling hot.

Wood may also be stained yellow by means of aqua fortis, which will sometimes produce a very beautiful yellow colour, but at other times a browner. Care must be taken, however, that the aqua fortis be not too strong, otherwise a blackish colour will be the result.

To stain Wood Red.

For a bright red stain for wood, make a strong infusion of Brazil wood in stale urine, or water impregnated with pearl-ashes, in the proportion of an ounce to a gallon; to a gallon of either of which, the proportion of Brazil wood must be a pound, which being put to them, they must stand together for two or three days, often stirring the mixture. With this infusion strained, and made boiling hot, brush over the wood to be stained till it appear strongly coloured; then, while yet wet, brush it over with alum-water made in the proportion of two ounces of alum to a quart of water.

For a less bright red, dissolve an ounce of dragon's blood in a pint of spirits of wine, and brush over the wood with the tincture till the stain appear to be as strong as is desired; but this is, in fact, rather lacquering than staining.

For a pink or rose red, add to a gallon of the above infusion of Brazil wood two additional ounces of the pearl-ashes, and use it as was before directed: but it is necessary, in this case, to brush the wood over with the alum-water. By increasing the proportion of pearl-ashes, the red may be rendered yet paler; but it is proper, when more than this quantity is added, to make the alum-water stronger.

To stain Wood Blue.

Wood may be stained blue by means either of copper or indigo.

The method of staining blue with copper is as follows: Make a solution of copper in aqua fortis, and brush it while hot several times over the wood; then make a solution of pearl-ashes in the proportion of two ounces to a pint of water, and brush it hot over the wood stained with the solution of copper, till it be of a perfectly blue colour.

To stain Wood Green.

Dissolve verdigrease in vinegar, or crystals of verdigrease in water, and with the hot solution brush over the wood till it be duly stained.

To stain Wood Purple.

Brush the wood to be stained several times with a strong decoction of logwood and Brazil, made in the proportion of one pound of the logwood and a quarter of a pound of the Brazil to a gallon of water, and boiled for an hour or more. When the wood has been brushed over till there be a sufficient body of colour, let it dry, and then be slightly passed over by a solution of one drachm of pearl-ashes in a quart of water. This solution must be carefully used, as it will gradually change the colour from a brown red, which it will be originally found to be, to a dark blue purple, and therefore its effect must be restrained to the due point for producing the colour desired.

To stain Wood a Mahogany Colour.

The substances used for staining mahogany colour are madder, Brazil wood, and logwood; each of which produce reddish brown stains, and they must be mixed together in such proportions as will produce the tint required.

To stain Wood Black.

Brush the wood several times over with a hot decoction of logwood. Then having prepared an infusion of galls by putting a quarter of a pound of powdered galls to two quarts of water, and setting them in the sunshine, or any other gentle heat, for three or four days, brush the wood over three or four times with it, and it will be of a beautiful black. It may be polished with a hard brush and shoemakers' black wax.

STAINING IVORY.

To stain Ivory Green.

Dissolve some copper or verdigrease in nitrous acid, and soak the ivory in it.

To stain Ivory Yellow.

Put a quarter of a pound of alum in a pint of water, boil the ivory in the solution; then boil it in a decoction of turmeric.

To stain Ivory Blue.

Boil it in the sulphate of indigo, and afterwards in a solution of three ounces of white tartar in a quart of water. Or it may be first stained green, and then dipped into a solution of pearl-ashes, made strong and boiling hot.

To stain Ivory Purple.

Put into nitrous acid one fourth of its weight of sal ammoniac; soak the ivory in it.

MISCELLANEOUS.

To make Phosphorus.

Phosphorus was formerly prepared from urine, and was therefore called *phosphorus of urine;* but it is exactly the same substance, from whatever materials it is procured. The following is a process for procuring it from bones, which consist chiefly of lime, combined with the phosphoric acid.

Take a quantity of bones; burn them to whiteness in an open fire, and reduce them to a fine powder. Upon three pounds of this powder, after having been put into a matrass, pour two pounds of concentrated sulphuric acid of commerce; four or five pounds of water must be afterwards added by degrees, to assist the action of the acid. During the process, the operator must place himself and the vessel so that the fumes of the mixture may be blown from him. The whole is then to be left in a sand-bath for about twelve hours, or more, taking care to supply the loss of water which happens by evaporation. The next day, a large quantity of water must be added; the clear liquor must be decanted, and the rest strained through a cloth or sieve. The residuary matter is to be washed by repeated affusions of hot water till it passes tasteless. The water which has been used to wash out the adhering acid is mixed with the decanted or strained liquor, and the whole fluid is gradually evaporated in a flat earthen bason to the consistence of a syrup. It is then mixed with an equal weight of charcoal powder, and submitted to distillation in an iron or earthen retort. Instead of using a receiver, the neck of the retort may be immersed in a bason of water, to a small depth, and the phosphorus, as it comes over, will fall in drops to the bottom.

Phosphorus made in this manner is blackish and dirty; it is purified by a second distillation. It may also be prepared from urine by the following method.

Dissolve as much lead in the nitric acid as it will act upon, and the solution will be nitrate of lead. Pour this into a quantity of urine, and a precipitate will be formed. When no more precipitate falls down by the addition of the solution, suffer the whole to stand undisturbed till it has all subsided, and then pour off the clear fluid. Make this precipitate into a paste with charcoal finely pounded, and dry it in an earthen pan gradually. Then put the mass into an iron or earthen retort, and distil it. The phosphorus will come over, and may be collected under water.

To make Canton's Phosphorus.

Take some oyster-shells; calcine them, by keeping them in a good fire for about an hour. Select out of the calcined shells the purest and whitest parts, and pound and sift them. To three parts of this lime add one of flowers of sulphur; mix them well together, and put them, well pressed, into a crucible. Place it in a good fire, where it must be kept red hot for an hour at least; it may then be taken out to cool. When it is cold, break the mass to pieces, and select out of it the brightest part, which will shine in the dark.

A beautiful representation of the telescopic appearance of one of the planets may be made by means of this. Cut out in paper the shape of the planet, such as a half moon, Saturn and his ring, &c., and cover it over with strong gum water; then strew some of this phosphorus, finely powdered, over the surface. When you want to exhibit it in the dark, you must previously expose it for a few minutes to the light of an ARGAND's lamp; or, what is better, make the flash from the discharge of a large electrical jar, or battery, pass over its surface, and it immediately becomes luminous, and exhibits a very exact resemblance of the planet.

To make Phosphoric Oil.

Put one part of phosphorus into six of olive-oil, and digest them over a sand heat. The phosphorus will dissolve. It must be kept well corked.

This oil has the property of being very luminous in the dark, and yet it has not sufficient heat to burn any thing. If rubbed on the face and hands, taking care to shut the eyes, the appearance is most hideously frightful; all the parts with which it has been rubbed appear to be covered with a very luminous lambent flame of a bluish colour, and the mouth and eyes appear in it as black spots. There is no danger attending this experiment. The light of it is sufficient to show the hour of the night on a watch, by holding it close to the bottle when it is unstopped.

To make Phosphorated Lime.

Put a few grains of phosphorus into the bottom of a Florence flask, and fill it up with quick-lime. Place it over a lamp till the phosphorus has sublimed, and is thoroughly mixed with the lime. If any of this lime be thrown out in the dark, it has the appearance of a shower of fire, but cannot burn any thing, as the quantity of phosphorus is too small to produce any sensible heat.

To make a Phosphoric Fire Bottle.

Take a very small phial, and put into it a bit of phosphorus as large as a pea, and fill up the bottle with lime. Fix an iron vessel, as a shovel, for instance, with common sand, and put it over the fire. Set the phial in this sand, having loosely stopped it with a cork. Stir about the ingredients with a wire, and mix them together; taking care that the phosphorus does not catch fire by too great an access of air. Keep the bottle in the sand till the phosphorus is thoroughly incorporated with the lime, when it will be of a reddish yellow.

This bottle is extremely convenient for procuring an instantaneous light in the dark. For this purpose, nothing more is necessary than to uncork the bottle, and to introduce a brimstone match, stirring it about a little, by which it will catch fire and light.

The bottle must be always kept carefully corked, and opened as seldom as possible.

A more durable kind may be made by uniting together one part of sulphur with eight of phosphorus. When this is used, a match is introduced into it, and then rubbed upon a bit of cork.

To make Phosphuret of Lime.

Put half an ounce of phosphorus, cut into small bits, into a glass tube about a foot long, and half an inch in diameter, closed at one end. Fill up with quick-lime grossly powdered, and stop the mouth of the tube loosely. Heat that part of the tube which contains the lime over a chafing-dish, till it be red hot; and then apply the heat of a lamp to the part containing the phosphorus, which will sublime, and mix with the lime. When cooled, the mixture will be a reddish mass.

If phosphuret of lime be dropped into water, air bubbles will be disengaged, which, on bursting at the top, will inflame with small explosions. They consist of phosphorated hydrogen gas.

To make Fulminating Powder.

Triturate in a warm mortar three parts, by weight, of nitre, two of mild vegetable alkali (carbonate of potash), and one of flowers of sulphur. A few grains of this laid upon a knife, and held over the candle, first fuses, and then explodes with a loud report. A drachm of it put into a shovel, and held over the fire, makes a noise as loud as a cannon, and indents the shovel as if it had received a violent blow.

To make Fulminating Mercury.

Dissolve 100 grains of mercury with heat, in a measured ounce and a half of nitric acid. This solution being poured cold upon two measured ounces of alcohol, previously introduced into any convenient glass vessel, a moderate heat is to be applied till effervescence is excited. A white fume then begins to undulate on the surface of the liquor, and the powder will be gradually precipitated on the cessation of action. The precipitate is to be immediately collected on a filtre, well washed with distilled water, and cautiously dried in a heat not exceeding that of a water bath. The immediate washing of the powder is material, because it is liable to the re-action of the nitric acid; and while any of the acid adheres to it, it is very subject to the action of light. From 100 grains of mercury, about 120 or 130 of the powder are obtained.

This powder, struck on an anvil with a hammer, explodes with a stunning disagreeable report; and with such force as to indent both the hammer and the anvil. Three or four grains are as much as ought to be used for such experiments.

To make the Arbor Dianæ, or Tree of Diana.

Take half an ounce of fine silver, and two drachms of mercury, and dissolve them separately in a quantity of aqua fortis. When the solutions are perfectly made, mix them together, and pour them into a pint of common water, and stir it about, that the whole may be well mixed. Keep this preparation in a bottle well corked. In a glass globe, or other vessel, put the quantity of a small nut of the amalgam of silver with mercury, and pour three or four ounces of the above liquor over it. After some hours there will arise from the little globular amalgam small branches, which, by increasing, will form a beautiful kind of shrub or tree of silver.

To make a Tree of Silver on Glass.

Put a few drops of the solution of silver in aqua fortis on a piece of glass, and having formed a bit of copper or brass-wire to represent a tree with its branches, but flat so as to lie upon the glass, lay it in the liquid, and let it remain for an hour or two. A beautiful vegetation will be perceived all round the wire, which will nearly be covered by it. This may be preserved by washing it very carefully with water, and putting another glass over it.

To produce a Tree of Lead.

Dissolve an ounce of sugar of lead in a quart of clear water, and put it into a glass decanter or globe. Then suspend in the solution, near the top, a small piece of zinc of an irregular shape. Let it stand undisturbed for a day, and it will begin to shoot out into leaves, and apparently to vegetate. If left undisturbed for a few days, it will become extremely beautiful; but it must be moved with great caution.

It may appear to those unacquainted with chemistry, that the piece of zinc actually puts out leaves; but this is a mistake, for if the zinc be examined, it will be found nearly unaltered. This phenomenon is owing to the zinc having a greater attraction for oxygen than the lead has; consequently, it takes it from the oxyde of lead, which re-appears in its metallic state.

Arbor Martis, or Tree of Mars.

Dissolve iron filings in aqua fortis moderately concentrated, till the acid is saturated; then add to it gradually a solution of fixed alcali, formerly called oil of tartar per deliquium. A strong effervescence will ensue, and the iron, instead of falling to the bottom of the vessel, will afterwards rise, so as to cover the sides, forming a multitude of ramifications heaped one upon the other, which will sometimes pass over the edge of the vessel, and extend themselves on the outside with all the appearance of a plant.

To change Iron apparently into Copper.

Dissolve some blue vitriol (sulphate of copper) in water, and dip into the solution a piece of bright iron or steel; in a few seconds it may be taken out, when it will be apparently turned to copper. This is a deception; the iron is not changed into copper; it is only encrusted over with that metal, as may be easily seen by removing the copper by a file. The iron having a stronger attraction for sulphuric acid than copper, it takes the acid from the latter, which is consequently precipitated. This process is used for obtaining the copper from waters near mines that contain a great quantity of that metal. Iron plates are put into them, which become incrusted with copper, which is scraped off.

To prepare the Precipitate of Cassius.

This beautiful purple colour is extremely useful to enamellers and glass stainers. To make it, proceed as follows.

Dissolve some gold in aqua regia (nitro-muriatic acid), and also dissolve some pure tin in diluted aqua regia, and pour it into the solution of gold. A purple powder will be precipitated, which must be collected and washed in distilled water.

A Method of Silvering Ivory.

Take a slip of ivory, immerse it in a weak solution of nitrate of silver, and let it remain in it till the ivory has acquired a bright yellow colour; then take it out of the solution, and immerse it in a tumbler of pure water, and expose it in the water to the rays of a very bright sun. After the ivory has been exposed to the sun's rays for about two or three hours, it becomes black; but on rubbing it a little, the black surface will become changed into one of silver. Although this coating of silver is extremely thin, yet if the ivory be well impregnated with the nitrate of silver, the solution will penetrate to a considerable depth; and as fast as the silver wears off from the surface of the ivory, the nitrate below being exposed to the light, is converted into silver, and the ivory retains its metallic appearance.

To cover Ribbons with Gold by a Chemical Process.

Let ether stand over phosphorus for some weeks, and some of the phosphorus will be dissolved. Dissolve also some gold in aqua regia (nitro-muriatic acid). Dip the ribbon, first, into the nitro-muriatic solution, and then into the phosphorated ether, and it will be covered with a firm coating of gold.

The same effect may be produced by exposing the ribbon, after having dipped it into the solution of gold, to a current of phosphorated hydrogen gas for some days.

To prepare Aurum Musivum.

Aurum musivum is used by japanners, and for many varnished works, as snuff-boxes, coaches, &c.

When well managed, it has all the beautiful appearance of gold in powder.

To make it, amalgamate twelve parts of the purest tin with three parts of mercury. The amalgam must then be triturated in a stone mortar with seven parts of flowers of sulphur, and three parts of sal ammoniac. The mixture is then put into a matrass, and the whole is exposed to a gentle sand heat, until no more white fumes arise. When, upon this, the heat is somewhat raised, cinnabar sublimes, together with some oxygenated muriate of tin; while, at the same time, the remaining tin unites with the remaining sulphur, and forms the aurum musivum, exhibiting a golden yellow and flakey or scaley matter, of a metallic lustre.

The main point in this process is the proper regulation of the fire: when this is too strong, the operation does not succeed; and instead of aurum musivum, common sulphuret of tin is obtained.

To make an Artificial Volcano.

For this curious experiment, which in some respects resembles the effect of volcanoes, we are indebted to Lemery.

Mix equal parts of pounded sulphur and iron-filings, and having formed the whole into a paste with water, bury a quantity of it, forty or fifty pounds, for example, at about the depth of a foot below the surface of the earth. In ten or twelve hours afterwards, if the weather be warm, the earth will swell up and burst, and flames will issue out, which will enlarge the aperture, scattering around a yellow and blackish dust.

It is not impossible, that what is here seen in miniature, takes place on a grand scale in volcanoes; as it is well known that they always furnish abundance of sulphur, and also metallic substances

To produce Artificial Lightning.

Provide a tin tube, that is much larger on one side than the other, and in which there are several holes. Fill this tube with resin, in powder, and when it is shook over the flame of a torch, it will produce a sudden corruscation that strongly represents a flash of lightning. This is the manner in which lightning is produced at the theatres: it is not the flame itself that is to be seen, but its reflection only, as happens for the most part in nature.

In this manner also the flambeaux of the furies on the stage are constructed, except that, at the end of each of them, there is a match dipped in spirits of wine; by means of which it is only necessary to shake them, and they will produce a sudden and very considerable flame.

Method of cutting Glass, by means of Heat.

Take a common wine-glass, or any vessel you want cut, and having heated a poker in the fire till it is almost red hot, but not quite, apply it to the part where you wish the crack to begin; having held it upon the part for about a minute, remove the poker, and wet the place: the glass will immediately crack. Having now begun the crack, you may lead it in any direction, by merely drawing the hot poker in the direction you want. This is extremely useful in many chemical experiments, where you are in want of proper apparatus.

Glass tubes may be easily cut with a file.

A Method of forming Pictures by Nitrate of Silver.

It is well known that light has a powerful effect upon many of the metallic oxydes, causing them to turn black.

Mr. J. Wedgewood has availed himself of this property, for copying paintings on glass, and making profiles of figures, by means of nitrate of silver.

Cover white paper, or leather, with a solution of nitrate of silver, and place it behind a painting on glass, which is exposed to the rays of the sun. The rays which come through will blacken the paper; but the shades will be more or less deep, in proportion to the quantities of light transmitted through the different parts of the glass. Where the glass is transparent, and all the light comes through, the paper will be made quite black; where the glass is quite opaque, and does not transmit any light, the paper will be quite white, and there will be degrees of intensity of the shadow of every variety between these.

This picture is not sensibly affected by the light of candles or lamps; but the day-light destroys it very soon, causing all the paper to become black; nor have any means, hitherto tried for preventing this, been successful.

Besides the application of this property of nitrate of silver to copying the light and shadow of paintings on glass, it may be applied to some others. By means of it delineations may be made of all such objects as are partly opaque and partly transparent. The fibres of leaves, and the wings of insects, may be pretty accurately represented by it, by only making the solar rays pass through them, upon prepared leather or paper.

Sir Humphrey Davy found, that the images of small objects produced by means of the solar microscope, may be copied without difficulty on prepared paper: the best proportion was one part of nitrate to about ten of water. This is sufficient to enable the paper to become tinged, without hurting its texture.

Artificial Fire-Works.

Artificial fire-works are of two kinds—those made of gunpowder, nitre, and other inflammable substances and filings of the metals, camphor, &c.; and those produced by hydrogen or inflammable air.

Those made with gunpowder are well known, and are called rockets, fire-wheels, tourbillons, &c.

Of these, the most usual are rockets. They are made by ramming into strong cylindrical paper cases put into wooden moulds, like small hollow columns, powdered gunpowder, or the ingredients of which it is composed; viz. saltpetre, sulphur, and charcoal, very dry.

If you would represent a fiery rain falling from the rocket, mix among your charge a composition of powdered glass, filings of iron, and saw dust; this shower is called the peacock's tail, on account of the various colours that appear in it. Camphor mixed with the charge produces white or pale fire; resin a reddish colour; sulphur a blue; sal ammoniac a green; antimony a reddish yellow; ivory shavings a silvery white, pitch a deep or dark coloured fire, and steel filings beautiful corruscations and sparks.

Sticks are fastened to the rockets by which they are projected into the air, after they have been lighted; the charge, burning with great intensity at one end, acts upon the air, which, in its turn, re-acts upon the rocket, and causes it to ascend, on the same principle as a boat is put off by a man in it who pushes against the shore with a boat-hook.

Fire-works by means of *inflammable air* are the most elegant; and being free from smell or smoke, may be exhibited in a room without any disagreeable effect.

By referring to what has been already said when treating on hydrogen gas, the principle of these fire-works will easily be understood. Small copper or tin tubes must be provided, of about a quarter of an inch in diameter; these tubes must be formed into the shapes required, and pierced with very small holes where a flame is wanted to appear; to these pieces must be attached large bladders, or air-tight bags, filled with hydrogen gas. There must also be a stop-cock between the tubes and the bladders, to open or close the communication. Having prepared every thing properly, open the stop-cock, and press the bladders; the hydrogen will be forced out through the holes in the tubes, and by means of a taper may be inflamed. A constant stream of fire may be kept up as long as there is any air in the bladders.

Upon this principle were constructed the beautiful fire-works exhibited in London by Mr. Cartwright.

The *philosophical candle*, formed by hydrogen, has been already described under chemistry.

Of Artificial Grottos and Shell-Work.

The idea of artificial grottos is often wrongly conceived. They are usually intended as imitations of nature; yet natural grottos are never seen ornamented within with shells, corals, pieces of looking-glass, &c., disposed in a *regular* manner. Sometimes, indeed, a more sober species of grotto is attempted, composed of rough masses of stone, representing natural rocks, and covered with moss, and various plants. The difficulties, however, in this art, considered as an imitation of nature, are much greater than most persons suppose. To succeed, the knowledge of the painter and the architect are necessary; and only those who have been accustomed to study nature with great attention, are sufficiently acquainted with natural forms. The chief aim should be to dispose the parts so that one may forget that the arrangement is artificial.

There is another idea, however, that may be entertained with regard to artificial grottos; which is, that they need not represent *natural caverns;* but the supposed productions of enchantment or magic. In this light, most of the incongruities will disappear, and every possible license may be given for the display of imagination and taste. Nothing is supposed to be impossible to magical power: therefore every species of natural or artificial productions may be combined together, and every thing introduced that may excite astonishment and surprise. Here there is no necessity for imitating the appearance of natural grottos, but every species of regularity and irregularity may be licensed. The sciences of architecture and mechanics may thus lend their aid in the construction of places, where mere nature is not the object of imitation, but where every thing may be employed that can have a powerful effect upon the imagination.

Shell-work, corals, statues, fountains, streams of water, paintings, curious musical pieces of mechanism; in short, every thing extraordinary, may be introduced with great success; and in this art there is an ample field for the display of taste.

The external of a grotto is the part where the least attempt at ornament should be made. It is best made to resemble some hermitage constructed of roots of trees, or some similar kind of structure; but no attempt should be made to imitate a natural cavern, except the situation should be peculiarly happy for this purpose.

A cement for fixing large shell-work and stones may be prepared as follows: Melt together a quantity of resin, pitch, and bees-wax, and add to it powdered marble or freestone, and a little sulphur. Any of the finer cements, mentioned under the article *cements*, may be used for delicate purposes.

To make Artificial Coral for Grottos.

To two drachms of fine vermilion add one ounce of clear resin, and melt them together. Having your branches or twigs peeled and dried, paint them over with this mixture while hot. The black thorn is the best branch for it. Hold them over a gentle fire, turning them round till they are perfectly covered and smooth. You may make white coral with white lead, and black with lamp-black.

To take Impressions from Leaves.

Take green leaves of trees or flowers, and lay them between the leaves of a book till they are dry. Then mix up some lamp-black with drying oil, and make a small dabber of some cotton wrapped up in a piece of soft leather. Put your colour upon a tile, and take some on your dabber. Laying the dried leaf flat upon a table, dab it very gently with the oil colour, till the veins of the leaf are covered; but you must be careful not to dab it so hard as to force the colour between the veins. Moisten a piece of paper, or rather have a piece laying between several sheets of moistened paper for several hours, and lay this over the leaf which has been blackened. Press it gently down, and then subject it to the action of a press, or lay a heavy weight on it, and press it down very hard. By this means you obtain a very beautiful impression of the leaf and all the veins; even the minutest will be represented in a more perfect manner than they could be drawn with the greatest care. These impressions may also be coloured in the same manner as prints.

A Method of making Pictures of Birds, by means of their own Feathers.

Get a thin board or pannel of deal, or wainscot, well seasoned, that it may not warp. Paste white paper over it, and let it dry. Take any bird that you would wish to represent, and draw its outline on the paper, in the attitude you desire, and of the full size, adding what landscape, back ground, &c. you wish. This outline, so drawn, is afterwards to be filled up with the feathers from the bird, placing each feather in that part of the drawing corresponding to the part of the bird it was taken from.

To do this, cover the representation with several coats of strong gum water, letting it dry between each coat, till it is of the thickness of a shilling.

When your ground is thus prepared, take the feathers off from the bird, beginning at the tail or the points of the wings, as you must work upwards towards the head. These feathers must be prepared by cutting off all the downy part; and the larger feathers must have the insides of their shafts pared off, to make them lie flat. To lay them on, make use of a pair of small pliers to hold them by; and moistening the gummed ground with water, place each feather in its natural and proper situation. Keep each feather down, by putting a small leaden weight upon it, till you have another prepared to lay on. You must be careful not to let the gum come through the feathers, as it smears them, and sticking to the bottoms of the weights, will be apt to pull the feathers off. When you have put on all the feathers, you must cut a piece of round paper, and colour it like the eye, which you may stick in its place; but the best way is to get small eyes made of glass. The bill, legs, and feet must be drawn and coloured from Nature. When it is finished and adjusted to your mind, lay a sheet of paper upon it, and upon that a heavy weight to press it; which must remain till the whole is quite dry.

To take the Impression of any Butterfly in all its Colours.

Having taken a butterfly, kill it without spoiling its wings, which contrive to spread out as regularly as possible in a flying position; then, with a small brush or pencil, take a piece of white paper; wash part of it with gum water, a little thicker than ordinary, so that it may easily dry; afterwards, laying your butterfly on the paper, cut off the body close to the wings, and throwing it away, lay the paper on a smooth board, with the fly upwards; and laying another paper over that, put the whole preparation into a screw press, and screw it down very hard, or otherwise press it, letting it remain under that pressure for half an hour. Afterwards take off the wings of the butterfly, and you will find a perfect impression of them, with all their various colours marked distinctly, remaining on the paper. When this is done, draw between the wings of your impression the body of the butterfly, and colour it after the insect itself.

To lay Mezzotinto Prints upon Glass.

Take what mezzotinto print you please; cut off the margin, and lay it flat in a dish of clear hot water; let it remain on the surface till it sinks. When you take it out, be careful not to break it, and press it betwixt clean cloths or papers, so that no water may appear on the surface, but the print be quite damp: then lay it, face uppermost, on a flat table; have ready a plate of pure crown glass, free from all spots or scratches; lay some Venice turpentine all over one side of it with a soft brush, and hold it to the fire a little, to make it run quite equal and thin; then let it fall gently on the print. Press it down, that the turpentine may stick to the print; and also press the print with your fingers, from the middle to the edges of the glass, so that no blisters may remain. Wet your print now with a soft cloth, and rub it gently with your finger, and the paper will peel off, leaving only the impression upon the glass. When it is dry, wet it ever with oil of turpentine till it is transparent, and set it by to dry, when it will be fit for painting. The colours used for painting in this manner are the usual oil colours, and there is nothing in the process particular.

To make Artificial Pearls.

Take the *blay* or *bleak fish*, which is very common in the rivers near London, and scrape off the fine silvery scales from the belly. Wash and rub these in water. Then suffer this water to settle, and a sediment will be found of an oily consistence. A little of this is to be dropped into a hollow glass bead of a bluish tint, and shaken about, so as to cover all the internal surface. After this, the bead is filled up with melted white wax, to give it solidity and weight.

To prepare the Nuremberg Powder of variegated Colour.

Mix together clean filings of copper, brass, iron, steel, and other metals. Put each of them separately into an iron vessel, and heat them till they change colour. The degree of heat can only be regulated by trial. Take these to a good flatting-mill, furnished with a funnel at top, and pass these filings through it, and you will procure a most beautiful sparkling powder of all sorts of lively colours.

To make very beautiful Artificial Petrifactions.

Put into a retort a quantity of pounded fluor spar and a few bits of broken glass, and pour upon them some sulphuric acid; fluoric acid gas will be disengaged, holding silex in solution. The substances to be made to resemble petrifactions, as lizards, frogs, branches of trees, birds nests, &c. must now be moistened with water, and placed in a vessel connected with the neck of the retort. The fluoric acid gas will be absorbed by the moisture adhering to the substances, and the silex will be precipitated upon them like a sort of hoar-frost, which will have a very beautiful appearance, and is very durable.

A Method of making Cast Steel.

This method has been invented in France. It is as follows: Take small pieces of iron, and place them in a crucible, with a mixture of chalk or lime-stone and the earth of Hessian crucibles. Six parts of chalk and six of this earth must be employed for twenty parts of the iron. The matters are to be so disposed, that, after fusion, the iron must be completely covered by them, to prevent it from coming into contact with the external air. The mixture is then to be gradually heated, and at last exposed to a heat capable of melting iron. If the fire be well kept up, an hour will generally be sufficient to convert two pounds of iron into excellent and exceedingly hard steel, capable of being forged; an advantage not possessed by steel made in the usual manner.

Method of distinguishing Iron from Steel.

Drop a little weak aqua-fortis on the metal; let it remain for a few minutes, and then wash it off with water. If it is steel, the spot will be black, but if iron, the spot will be whitish grey.

A Test for discovering the presence of Lead, Copper, &c. in Wines.

Lead and copper being sometimes used to amend the taste of wines, and these metals being of a very poisonous quality, a test that shall detect this is of great value. The following test is the discovery of Mr. Hanhemann.

Equal parts of oyster shells and crude sulphur are to be kept in a white heat for a quarter of an hour, and, when cold, this is to be mixed with an equal quantity of acidulous tartrite of potash, and put into a strong bottle with common water for an hour, and then decanted into bottles holding an ounce each, with twenty drops of muriatic acid in each.

This liquor precipitates the least quantities of lead, copper, &c. from wines, in a very sensible black precipitate.

To make Pearl White.

Put some good aqua-fortis into a Florence flask, and gradually add to it bismuth broken into small pieces, till no more dissolves; then let the solution remain till it is transparent. Add to this some water, and a white precipitate will be formed, which is to be washed and dried. This is white oxyde of bismuth, commonly termed *magistery of bismuth*, or *pearl-white.*

This is used as a cosmetic, and is sold by the perfumers; but it very much impairs the skin, blackening it by degrees, so that once used, it must be continued; and it is also to be feared, that it has, besides, deleterious effects upon the constitution.

To procure Animalculæ for the Microscope.

The surface of infused liquors is generally covered with a thin pellicle, which is easily broken, but acquires thickness by standing; the greatest number of animalculæ are generally to be found in this superficial film.

To make an infusion of pepper.—Cover the bottom of an open jar, about half an inch thick, with common black pepper, bruised; pour as much soft water in the vessel as will rise about an inch above the pepper. The pepper and water are then to be well shaken together; after which they must not be stirred, but be left exposed to the air for a few days, when a thin pellicle will be formed on the surface of the water, containing millions of animalculæ.

To procure the eels in paste.—Boil a little flour and water till it becomes of a moderate consistence; expose it to the air in an open vessel, and beat it together from time to time, to prevent the surface from growing hard or mouldy: after a few days, especially in summer time, it will turn sour; then, if it be examined with attention, you will find myriads of eels on the surface. Apply them to the microscope on a slip of flat glass, first putting on it a drop of water, taken up by the head of a pin, for them to swim in.

A very useful Method of breaking up Logs of Wood.

The usual way of breaking up logs of wood for the purposes of fuel, is by axes, and driving wedges in. This, particularly in roots of trees, is very laborious. It is also sometimes done by gunpowder, in the same way as stones and rocks are blasted; but this is very troublesome, as the plug is often driven out. A better method of performing this operation has lately been invented. A hole is bored with an augre, and a charge of powder introduced. An iron screw, with a good thread, having a hole bored through its axis, is then introduced into the hole, and turned till it come near to the powder. While the screw is putting in, a wire is kept in the hole through its axis, but it is afterwards drawn out, and a piece of twine dipped in a solution of nitre is put into its place. This quick match is set fire to, and by its slow burning, affords time for the operator to retire before it sets fire to the gunpowder.

By this means, any roots or old stumps of trees may be easily broken up.

A Process for purifying Fish Oil.

Take a gallon of crude stinking oil, and put to it a pint of water poured off from two ounces of lime slacked in the air; stir the mixture up several times for the first twenty-four hours; then let it stand a day, and the lime water will sink below the oil, which must be carefully separated from it.

Another Method for purifying it more completely.

Take a gallon of crude stinking oil, and mix with it a quarter of an ounce of powdered chalk, a quarter of an ounce of lime slacked in the air, and half a pint of water; stir them together; and when they have stood some hours, add a pint of water, and two ounces of pearl-ashes, and place the mixture over a fire that will just keep it simmering, till the oil appears of a light amber colour, and has lost all smell, except a hot, greasy, soap-like scent. Then superadd half a pint of water, in which one ounce of salt has been dissolved, and having boiled it half an hour, pour the mixture into a proper vessel, and let it stand for some days, till the oil and water separate.

If this operation be repeated several times, diminishing each time the quantity of ingredients one-half, the oil may be brought to a very light colour, and rendered equally sweet with the common spermaceti oil.

Oil purified in this manner is found to burn much better, and to answer better the purposes of the woollen manufacture. If an oil be wanted thicker and more unctuous, this may be rendered so by the addition of tallow or fat.

FINE ARTS.

Under the name of *Fine* or *Polite Arts*, have been generally comprehended, painting, sculpture, architecture, poetry, and music: but in the common acceptation of words, the term fine arts is usually confined to the three first; and the professors of them are called, by way of eminence, *artists*.

It would exceed the limits to which we are confined in this work, to descant on the value and importance of the fine arts; and it is the less necessary, as this subject is beginning to be generally understood, since drawing has become a necessary branch of education.

To treat fully and professionally on the fine arts, would require a separate and extended work. What is here proposed, is to consider that part which enters into our system of usual school education.

Drawing strictly means the delineation of the *contours* or *outlines* of objects: and in this sense the term is used by painters, who distinguish between drawing and colouring: but the meaning of the word drawing is not sufficiently restricted, since, in common language, it has been applied to all such paintings as are executed with water colours on paper; the title of *paintings* having been rather given to those executed with oil colours on canvass.

Since this difference of the materials *only* afforded a very bad ground of distinction on which to found two species, the term *paintings in water colours* has very properly been lately introduced.

Still, however, in common language, the name of drawings is given to all works in water-colours, whether in outline only, in black and white, or in colours; and the term paintings to those in oil.

Painting in oil is capable of the greatest degree of perfection, but is also the most difficult, and is seldom attempted but by professional artists: whereas, the use of water-colours is comparatively easier, and better adapted for common use.

The first step in the arts is to learn to draw the outlines of objects: next to express the light and shadow: and, lastly, to add the colour.

But before we proceed, it will be necessary to describe the implements and colours made use of.

Implements for Drawing.

Drawing-boards are for fixing the paper upon, so that it may not shift, and also for straining it, to prevent the colours, when laid wet upon the paper, from causing it to swell up, so as to be uneven. The simplest sort is made of a deal board framed square, with a strong piece across each end, to prevent warping. Upon this the paper may be fixed down with pins, wafers, or sealing-wax, or it may be strained with paste or glue, as follows: having wetted the paper well with a sponge, lay it upon the board, and turning up the edges about half an inch, run a little good paste or glue all round on the under side, and press the paper down upon the board with a cloth; then set it by to dry: the paper, which had expanded and blistered up much when wet, will contract in drying, while the edges, being fixed immoveably, will strain quite flat and tight, and will be much better for drawing upon than when loose.

The best kind of drawing-boards, however, are made with a frame and a moveable pannel, upon which the paper is simply put wet, and then forced into the frame, where it is confined by wedges at the back. This strains equally well without the trouble of pasting, so that you may dry it at the fire; and it also looks much neater. These drawing-boards may be bought at most colour-shops. It is necessary to mention, that all the angles of drawing-boards should be exactly square.

Parallel rulers are for drawing parallel lines readily: they are made of two pieces of ebony fastened together by brass bars, so as always to move parallel to each other. They may be bought of different kinds and prices, at the mathematical instrument makers.

Tee-squares are rulers made in the form of the letter T, which are used with the drawing-boards; the short end, called the stock, being applied to the edge of the board, so as to slide forwards and backwards; while the long part, called the blade, is used for drawing lines by. These are more convenient than parallel rulers, when a drawing-board is used, as by them you draw lines at right angles to each other at once, without using the compasses.

Dividing compasses are instruments of brass and steel, for dividing lines, and laying down measures from scales, &c.: they are generally sold in cases, containing also a steel pen for drawing lines cleaner than can be done by a common pen, which is very useful where neatness is required; and points with a black lead pencil, for putting into the compasses, when circles are to be described. These cases also contain scales of equal parts, and protractors for laying down angles. All these may be had at the instrument makers.

Black lead pencils are made of plumbago sawed into slips, and fitted into sticks of cedar. They are of various qualities. The best are fine, without any grit, not too soft, and that cut easily without breaking. An inferior kind is made by mixing up the dust of plumbago with gum or glue, and thus forming a composition, which is fitted into sticks in the same manner as the best: these are always gritty, and do not answer so well for most drawings; yet, being cheaper, they may be used upon many occasions. It is necessary to examine pencils before any quantity is bought, by cutting one of them, because the composition pencils, having the same outward appearance, are often sold for the best.

Indian rubber, or elastic gum, as it is also called, is a substance much like leather, which has the curious and useful property of erasing or defacing lines drawn with black lead; it is, therefore, much used for this purpose. It is brought chiefly from South America, in the form of small bottles, which are cut up into slips. It is originally the juice of a tree that grows very abundantly in Surinam, and is like milk when exuded from the tree, but soon becomes solid when exposed to the air. The natives form balls of clay, which they smear over with this milk: when this coating is almost dry, they apply another, and so on, till it is of the required thickness; they then moisten the clay with water, which does not dissolve the Indian rubber, and wash it out. These bottles are used by the natives for containing water, or other liquors. It is a production common to the East Indies also, from whence it is imported in various forms, more convenient for use than the bottles abovementioned.

Indian Ink.—This very useful substance comes from China, where it is used for common writing, which is there performed with a brush instead of a pen. It is a solid substance, of a brownish black colour. When ground up with water upon a clean tile or earthenware plate, it may be made either lighter or darker, as required, by adding to it more or less water. The best Indian ink is always stamped with Chinese characters, breaks with a glossy fracture, and feels smooth, and not gritty, when rubbed against the teeth. The composition is not accurately known. An inferior kind is made in this country; but it may be easily distinguished by its grittiness. This is made of lamp black or ivory black, ground up with gum.

Hair pencils are made of camel's hair, put into a goose or swan's quill. To choose these, moisten them a little, and if they come to a point without splitting, they are good; if they do not, they are not fit for drawing with.

Charcoal is used for slightly sketching in the outlines of figures, in order to get the proportions, previous to making a drawing in chalk. The best charcoal for this purpose is that of the willow; it is cut into slips, and the strokes made with it may easily be rubbed out with a feather of goose's or duck's wing.

Black chalk is a fossil substance resembling slaty coal, which is cut into slips for drawing. It is generally used in an instrument called a *port crayon*, which is made either of steel or brass. It is much employed for drawing figures, and is the best substance for this purpose, in making drawings from plaster, or after the life. It is more gritty than black lead, but is of a deeper black, and has not the glossiness of the former. It is of two kinds, French and Italian; the former is soft, the latter hard.

For mellowing and softening the shadows into each other when black chalk is used,

Stumps are necessary. They are pieces of soft shamoy leather, or blue paper, rolled up quite tight, and cut to a point.

White chalk is used together with black, for laying on the lights. This is different from common chalk, being much harder. Tobacco-pipe clay will do very well instead of it.

Red chalk is a fossil substance of a red ochrey colour, which is sometimes used for drawing, but not so much now as it formerly was, the black being preferred; however, the red being cheaper, will do very well for some purposes.

Drawing paper.—Any paper that will do for writing will do for drawing; but as the wire-marks in common writing paper are injurious, paper made without any wire-marks, called *wove paper*, is generally used for this purpose. It is made of various sizes and thickness.

Middle tint paper is paper of a brownish or of a grey colour, which is used for drawing upon with black and white chalk. Being of a dark colour, the strokes of the white chalk are distinctly seen; and it saves a great deal of time in making drawings, as the tint of the paper answers for the half shadow, so that all that is necessary to be done, is to lay in the dark shadows and the lights.

GEOMETRY.

Various are the opinions upon the best modes of beginning to learn to draw: and it is by no means easy to decide upon this point, as so much must always depend upon the genius, turn of mind, and opportunities of the student. But, for general purposes, and when circumstances will admit of it, we have no hesitation in recommending to begin by the study of geometry and perspective.

The first forms the best introduction to a knowledge of form, by giving accurate ideas respecting the most simple forms, of which all the others may be considered as compounds: and the last is absolutely necessary, not only to enable us to draw the representations of regular objects, but even to see them correctly: and it is certain that no one unacquainted with its rules can ever attain the power of drawing, without making the grossest mistakes.

Geometry is a branch of mathematics which treats of the description and properties of magnitudes in general.

Definitions or Explanations of Terms.

1. A *point* has neither length, breadth, nor thickness. From this definition it may easily be understood that a mathematical point cannot be seen nor felt; it can only be imagined. What is commonly called a point, as a small dot made with a pencil or pen, or the point of a needle, is not in reality a mathematical point; for however small such a dot may be, yet, if it be examined with a magnifying glass, it will be found to be an irregular

spot, of a very sensible length and breadth; and our not being able to measure its dimensions with the naked eye, arises only from its smallness. The same reasoning may be applied to every thing that is usually called a point; even the point of the finest needle appears like that of a poker when examined with the microscope.

2. A *line* is length, without breadth or thickness. What was said above of a point, is also applicable to the definition of a line. What is drawn upon paper with a pencil or pen, is not, in fact, a line, but the representation of a line. For however fine you may make these representations, they will still have some breadth. But by the definition, a line has no breadth whatever; yet it is impossible to draw any thing so fine as to have no breadth. A line, therefore, can only be imagined. The ends of a line are points.

3. *Parallel* lines are such as always keep at the same distance from each other, and which, if prolonged ever so far, would never meet. Pl. 3. Fig. 1.

4. A *right line* is what is commonly called a *straight* line, or that tends every where the same way.

5. A *curve* is a line which continually changes its direction between its extreme points.

6. An *angle* is the inclination or opening of two lines meeting in a point, Fig. 2.

7. The lines A B, and B C, which form the angle, are called the legs or sides; and the point B where they meet, is called the *vertex* of the angle, or the *angular point.* An angle is sometimes expressed by a letter placed at the vertex, as the angle B, Fig. 2: but most commonly by three letters, observing to place in the middle the

letter at the vertex, and the other two at the end of each leg, as the angle A B C.

8. When one line stands upon another, so as not to lean more to one side than to another, both the angles which it makes with the other are called *right-angles*, as the angles A B C and A B D, Fig. 3, and all right-angles are equal to each other, being all equal to 90°; and the line A B is said to be *perpendicular* to C D.

Beginners are very apt to confound the terms *perpendicular*, and *plumb* or *vertical line*. A line is vertical when it is at right-angles to the plane of the horizon, or level surface of the earth, or to the surface of water, which is always level. The sides of a house are vertical. But a line may be perpendicular to another, whether it stands upright or inclines to the ground, or even if it lies flat upon it, provided only that it makes the two angles formed by meeting with the other line equal to each other; as for instance, if the angles A B C, and A B D be equal, the line AB is perpendicular to CD, whatever may be its position in other respects.

9. When one line, BE (Fig. 3), stands upon another, C D, so as to incline, the angle E B C, which is greater than a right-angle, is called an *obtuse* angle; and that which is less than a right-angle, is called an *acute* angle, as the angle E B D.

10. Two angles which have one leg in common, as the angles ABC, and ABE, are called *contiguous* angles, or *adjoining* angles; those which are produced by the crossing of two lines, as the angles E B D and CBF, formed by C D and E F, crossing each other, are called *opposite* or *vertical* angles.

11. A *figure* is a bounded space, and is either a *surface* or a *solid*.

12. A *superficies*, or *surface*, has length and breadth only. The extremities of a superficies are lines.

A *plane*, or *plane surface*, is that which is every where perfectly flat and even, or which will touch every part of a straight line, in whatever direction it may be laid upon it. The top of a marble slab, for instance, is an example of this, which a straight edge will touch in every point, so that you cannot see light any where between.

A *curved surface* is that which will not coincide with a straight line in any part. Curved surfaces may be either convex or concave.

A *convex surface* is when the surface rises up in the middle, as, for instance, a part of the outside of a globe.

A *concave surface* is when it sinks in the middle, or is hollow, and is the contrary to convex.

A surface may be bounded either by straight lines, curved lines, or both these.

13. Every surface bounded by straight lines only, is called a *rectilinear figure*.

14. Three is the fewest number of sides that a rectilinear figure can have; and it is then called a *triangle*.

15. *Triangles* are of different kinds, according to the *lengths of their sides*.

An *equilateral triangle* has all its sides equal, as A B C, Fig. 4.

An *isosceles triangle* has two equal sides, as D E F, Fig. 5.

A *scalene triangle* has all its sides unequal, as G H I, Fig. 6.

16. Triangles are also denominated according to the *angles they contain*.

A *right-angled* triangle is one that has in it a right-angle, as A B C, Fig. 7.

A triangle cannot have more than one right-angle. The side opposite to the right-angle B, as AC, is called the *hypothenuse*, and is always the longest side.

An *obtuse-angled* triangle has one obtuse angle, as Fig. 8.

An *acute-angled* triangle has all its angles acute, as Fig. 4.

An isosceles, or a scalene triangle, may be either right-angled, obtuse, or acute.

Any side of a triangle is said to *subtend* the angle opposite to it: thus A B (Fig. 7), subtends the angle A C B.

If the side of a triangle be drawn out beyond the figure, as A D (Fig. 8), the angle A, or C A B, is called an *internal* angle, and the angle C A D, or that without the figure, an *external* angle.

17. A figure with four sides is called a *quadrilateral* figure. They are of various denominations, as their sides are equal or unequal, or as all their angles are right angles or not.

18. Every four-sided figure whose opposite sides are parallel, is called a *parallelogram.* Provided that the sides opposite to each other be parallel, it is immaterial whether the angles are right or not. Fig. 9, 10, 11, and 12, are all parallelograms.

When the angles of a parallelogram are all right angles, it is called a *rectangular parallelogram*, or a *rectangle*, as Fig. 11 and 12.

19. A rectangle may have all its sides equal, or only the opposite sides equal. When all its sides are equal, it is called a *square*, as Fig. 12.

20. When the opposite sides are parallel, and all the sides equal to each other, but the angles not

right angles, the parallelogram is called a *rhombus*, as Fig. 10.

21. A parallelogram having all its angles oblique, and only its opposite equal, is called a *rhomboid*, as Fig. 9.

22. When a quadrilateral or four-sided figure has none of its sides parallel, it is called a *trapezium*, as Fig. 13.; consequently every quadrangle, or quadrilateral which is not a parallelogram, is a trapezium.

23. A *trapezoid* has only one pair of its sides parallel, as Fig. 14.

24. A *diagonal* is a right line drawn between any two angles that are opposite in a quadrangle, as I K, Fig. 15. In parallelograms the diagonal is sometimes called the *diameter*, because it passes through the centre of the figure.

25. *Complements* of a parallelogram. If any point, as E (Fig. 15.), be taken in the diagonal of a parallelogram, and through that point two lines are drawn parallel to the sides, as A B, C D, it will be divided into four parallelograms, D D, L, F, G G. The two divisions, L, F, through which the diameter does not pass, are called the complements.

26. Figures having more than four sides are called *polygons*. If the sides are all equal, they are called *regular polygons*: if they are unequal, they are called *irregular polygons*.

A pentagon is a polygon of five sides.
A hexagon has six sides.
A heptagon seven sides.
An octagon eight sides.
A nonagon nine sides.
An undecagon eleven sides.
A duodecagon twelve sides.

When they have a greater number of sides, they are called polygons of 13 sides, of 14 sides, and so on.

27. *Base* of a figure is the side on which it is supposed to stand erect, as A B and C D. (Fig. 16.)

28. *Altitude* of a figure is its perpendicular height from the base to the highest part, as E F. (Fig. 16.)

29. *Area* of a plane figure, or other surface, means the quantity of space contained within its boundaries, expressed in square feet, yards, or any other superficial measure.

30. *Similar figures* are such as have the same angles, and whose sides are in the same proportion, as Fig. 17.

31. *Equal* figures are such as have the same area or contents.

32. A *circle* is a plane figure, bounded by a curve line returning into itself, called its *circumference*, ABCD, (Fig. 18.) every where equally distant from a point E within the circle, which is called the *centre*.

33. The *radius* of a circle is a straight line drawn from the centre to the circumference, as E F. (Fig. 18.) The radius is the opening of the compass when a circle is described; and consequently all the radii of a circle must be equal to each other.

34. A *diameter* of a circle is a straight line drawn from one side of the circumference to the other through the centre, as C B. (Fig. 18.) Every diameter divides the circle into two equal parts.

35. A *segment* of a circle is a part of a circle cut off by a straight line drawn across it. This straight line is called the *chord*. A segment may be either equal to, greater, or less than a *semicircle*, which is

a segment formed by the diameter of the circle, as C E B, and is equal to half the circle.

36. A *tangent* is a straight line drawn so as just to touch a circle without cutting it, as G H. (Fig. 18.) The point A, where it touches the circle, is called the *point of contact.* And a tangent cannot touch a circle in more points than one.

37. A *sector* of a circle is a space comprehended between two radii and an arc, as B I K. (Fig. 19.)

38. The circumference of every circle, whether great or small, is supposed to be divided into 360 equal parts, called *degrees;* and every degree into 60 parts, called minutes; and every minute into 60 seconds. To measure the inclination of lines to each other, or angles, a circle is described round the angular point as a centre, as I K, Fig. 19.; and according to the number of degrees, minutes, and seconds, cut off by the sides of the angle, so many degrees, minutes, and seconds, it is said to contain. Degrees are marked by °, minutes by ′, and seconds by ″; thus an angle of 48 degrees, 15 minutes, and 7 seconds, is written in this manner, 48° 15′ 7″.

39. A *solid* is any body that has length, breadth, and thickness: a book, for instance, is solid, so is a sheet of paper; for though its thickness is very small, yet it has some thickness. The boundaries of a solid are *surfaces.*

40. *Similar solids* are such as are bounded by an equal number of similar planes.

41. A *prism* is a solid, of which the sides are parallelograms, and the two ends or bases are similar polygons, parallel to each other. Prisms are denominated according to the number of angles in the base, *triangular* prisms, *quadrangular*, *pentangular*, and so on, as Fig. 20, 21, 22, 23. If the

sides are perpendicular to the plane of the base, it is called an *upright* prism; if they are inclined, it is called an *oblique* prism.

42. When the base of a prism is a parallelogram, it is called a *parallelopipedon*, as Fig. 22. and 23. Hence a parallelopipedon is a solid terminated by six parallelograms.

43. When all the sides of a parallelopipedon are squares, the solid is called a *cube*, as Fig. 23.

44. A *rhomboid* is an oblique prism, whose bases are parallelograms. (Fig. 24.)

45. A *pyramid*, A B, (Fig. 25. and 26.) is a solid bounded by, or contained within a number of planes, whose base may be any rectilinear figure, and whose faces are triangles terminated in one point, B, commonly called the *summit*, or *vertex* of the pyramid.

When the figure of the base is a triangle, it is called a *triangular pyramid;* when the figure of the base is quadrilateral, it is called a *quadrilateral pyramid*, &c.

A pyramid is either *regular* or *irregular*, according as the base is regular or irregular.

A pyramid is also *right* or *upright*, or it is *oblique*. It is *right*, when a line drawn from the vertex to the centre of the base, is perpendicular to it, as Fig. 25.; and *oblique*, when this line inclines, as Fig. 26.

46. A *cylinder* is a solid (Fig. 27. and 28.) generated or formed by the rotation of a rectangle about one of its sides, supposed to be at rest; this quiescent side is called the *axis* of the cylinder. Or it may be conceived to be generated by the motion of a circle, in a direction perpendicular to its surface, and always parallel to itself.

A cylinder is either *right* or *oblique*, as the axis is perpendicular to the base or inclined.

Every *section* of a right cylinder taken at right angles to its axis is a *circle;* and every section taken across the cylinder, but oblique to the axis, is an *ellipsis*.

As a circle may be considered to be a polygon of an infinite number of sides, so a cylinder may be conceived as a prism having such polygons for bases.

47. A *cone* is a solid, (Fig. 29. and 30.) having for its base a circle, and its sides a convex surface, and terminating in a point A called the *vertex* or *apex* of the cone. It may be conceived to be generated by the revolution of a right-angled triangle about its perpendicular.

A line drawn from the vertex to the centre of the base, is the *axis* of the cone.

When this line is perpendicular to the base, the cone is called an upright or *right* cone; but when it is inclined, it is called an *oblique* cone.

If a cone be cut through the axis from the vertex to the base, the section will be a *triangle*.

If a right cone be cut by a plane at right angles to the axis, the section will be a *circle*.

If a cone be cut oblique to the axis, and quite across from one side to the other, the section will be an *ellipsis*, as Fig. 31. A section of a cylinder made in the same manner, is also an ellipsis; and this is easily conceived; but it does not appear so readily to most people, that the oblique section of a cone is an ellipsis: they frequently imagine that it will be wider at one end than the other, or what is called an *oval*, which is of the shape of an egg. But that this is a mistake, any one may convince himself, by making a cone, and cutting it across obliquely: it will be then seen that the section, in whatever direction it is taken, is a regular ellipsis; and this is the case, whether the cone be right or oblique; except only in one case in the oblique cone, which is when the section is taken in a particular direction which is called *sub-contrary* to its base.

48. When the section is made parallel to one of the sides of the cone, as Fig. 32., the curve A B C, which bounds the section, is called a *parabola*.

49. When the section is taken parallel to the axis, as Fig. 33., the curve is called an *hyperbola*.

The curves which are formed by cutting a cone in different directions are called *conic sections*, and have various properties which are of great importance in astronomy, gunnery, perspective, and many other sciences.

50. A *sphere* is a solid, terminated by a convex surface, every point of which is at an equal distance from a point within called the *centre*. Fig. 34.

It may be conceived to be formed by making a semicircle revolve round its diameter. This may be illustrated by the process of forming a ball of clay by the potter's wheel, a semicircular mould being used for the purpose. The diameter of the semicircle round which it revolves is called the *axis* of the sphere.

The ends of the axis are called *poles*.

Any line passing through the centre of the sphere, and terminated by the circumference, is a *diameter* of the sphere.

Every section of a sphere is a circle; every section taken through the centre of the sphere, is called a *great circle*, as A B, Fig. 34.; every other is a *lesser circle*, as C D.

Any portion of a sphere cut off by a plane is called a *segment*; and when the plane passes through the centre, it divides the sphere into two equal parts, each of which is called a *hemisphere.*

51. A *conoid* is a solid produced by the circumvolution of a section of the cone about its axis; and consequently may be either an *elliptical conoid*, a *hyperbolical conoid*, or a *parabolical conoid.* When it is elliptical, it is generally called a *spheroid.* These solids are also called *ellipsoid*, *hyperboloid*, and *paraboloid.*

52. A *spheroid* is a solid (Fig. 35.) generated by the rotation of a semi-ellipsis about the transverse or conjugate axis; and the centre of the ellipsis is the centre of the spheroid.

The line about which the ellipsis revolves, is called the *axis.* If the spheroid be generated about the conjugate axis of the semi-ellipsis, it is called a *prolate spheroid.*

If the spheroid be generated by the semi-ellipsis by revolving about the transverse axis, it is called an *oblong spheroid.*

Every *section* of a spheroid is an *ellipsis*, except when it is perpendicular to that axis about which it is generated; in which case it is a circle.

All sections of a spheroid parallel to each other are similar figures.

A *frustum* of a solid means a piece cut off from the solid by a plane passed through it, usually parallel to the base of the solid; as the frustum of a cone, a pyramid, &c.

There is a *lower* and an *upper* frustum, according as the piece spoken of does or does not contain the base of the solid.

53. *Ratio* is the proportion which one magnitude bears to another of the same kind, with respect to quantity; and is usually marked thus, A : B.

Of these, the first is called the *antecedent*, and the second the *consequent*.

The *measure* or *quantity* of a ratio is conceived by considering what part of the consequent is the antecedent; consequently it is obtained by dividing the consequent by the antecedent.

54. *Three* magnitudes or quantities, A,B,C, are said to be *proportional*, when the ratio of the first to the second is the same as that of the second to the third. Thus, 2, 4, 8, are proportional, because 4 is contained in 8 as many times as 2 is in 4.

55. *Four* quantities, A,B,C,D, are said to be *proportional* when the ratio of the first A to the second B is the same as the ratio of the third C to the fourth D. It is usually written A : B : : C : D, or, if expressed in numbers, 2 : 4 : : 8 : 16.

56. Of *three* proportional quantities, the middle one is said to be a *mean proportional* between the other two; and the last a *third proportional* to the first and second.

57. Of *four* proportional quantities, the last is said to be a *fourth proportional* to the other three, taken in order.

58. *Ratio of equality* is that which equal numbers bear to each other.

59. *Inverse ratio* is when the antecedent is made the consequent, and the consequent the antecedent. Thus if 1 : 2 : : 3 : 6; then *inversely*, 2 : 1 : : 6 : 3.

60. *Alternate proportion* is when antecedent is compared with antecedent, and consequent with consequent. Thus if 2 : 1 : : 6 : 3; then by *alternation*, 2 : 6 : : 1 : 3.

61. Proportion by *composition* is when the antecedent and consequent, taken as one quantity, are compared either with the consequent or with the antecedent. Thus if 2 : 1 : : 6 : 3; then by *composition* 2+1 : 1 : : 6+3 : 3, and 2+1 : 2 : 6+3 : 6.

62. *Divided proportion* is when the difference of the antecedent and consequent is compared either with the consequent or with the antecedent. Thus if 3 : 1 : : 12 : 4; then by *division* 3 — 1 : 1 : : 12 — 4 : 4 and 3 — 1 : 3 : : 12 — 4 : 12.

63. *Continued proportion* is when the first is to the second as the second to the third; as the third to the fourth; as the fourth to the fifth; and so on.

64. *Compound ratio* is formed by the multiplication of several antecedents and the several consequents of ratios together, in the following manner:

If A be to B as 3 to 5, B to C as 5 to 8, and C to D as 8 to 6; then A will be D, as $\frac{3\times5\times8}{5\times8\times6}=\frac{120}{240}=\frac{1}{2}$; that is, A : D : : 1 : 2.

65. To *Bisect* means to divide any thing into two equal parts.

66. To *Trisect* is to divide any thing into three equal parts.

67. To *Inscribe* is to draw one figure within another, so that all the angles of the inner figure shall touch either the angles, sides, or planes of the external figure.

68. To *Circumscribe* is to draw a figure round another, so that either the angles, sides, or planes of the circumscribed figure shall touch all the angles of the figure within it.

69. A *Rectangle under any two lines* means a rectangle which has two of its sides equal to one of the lines, and two of them equal to the other. Also the rectangle under AB,CD, means AB×CD.

70. *Scales of equal parts.* A scale of equal parts is a straight line divided into any number of equal parts at pleasure. Each part may represent any measure you please, as an inch, a foot, a yard, &c. One of these is generally subdivided into parts of the next denomination, or into tenths or hundredths.

Scales may be constructed in a variety of ways. The most usual manner is to make an inch, or some aliquot part of an inch to represent a foot; and then they are called inch scales, three-quarter-inch scales, half-inch scales, quarter-inch scales, &c. They are usually drawn upon ivory or box-wood.

71. An *axiom* is a manifest truth, not requiring any demonstration.

72. *Postulates* are things required to be granted true, before we proceed to demonstrate a proposition.

73. A *proposition* is when something is either proposed to be done, or to be demonstrated, and is either a *problem* or a *theorem.*

74. A problem is when something is proposed to be done; as some figure to be drawn.

75. A *theorem* is when something is proposed to be demonstrated or proved.

76. A *lemma* is when a premise is demonstrated, in order to render the thing in hand the more easy.

77. A *corollary* is an inference drawn from the demonstration of some proposition.

78. A *scholium* is when some remark or observation is made upon something mentioned before.

79. The sign = denotes that the quantities betwixt which it stands are equal.

80. The sign + denotes that the quantity after it is to be added to that immediately before it.

81. The sign — denotes that the quantity after it is to be taken away or subtracted from the quantity preceding it.

Geometrical Problems.

Prob. 1. To divide a given line, A B (Pl. 4.), into two equal parts.

From the points A and B as centres, and with any opening of the compasses greater than half A B, describe arches cutting each other in *c* and *d*. Draw the line *c d*; and the point E, where it cuts A B, will be the middle required.

Prob. 2. To raise a perpendicular to a given line A B, from a point given at C.

Case 1. When the given point is near the middle of the line. On each side of the point C, take any two equal distances C *d* and C *e*; from *d* and *e*, with any radius or opening of the compasses greater than C *d*, or C *e*, describe two arcs cutting each other in *f*. Lastly, through the points *f*, C, draw the line *f*C, and it will be the perpendicular required.

Case 2. When the point is at or near the end of the line. Take any point *d*, above the line, and with the radius or distance *d* C, describe the arc *e* C *f*, cutting A B in *e* and C. Through the centre *d*, and the point *e*, draw the line *e d f*, cutting the arc *e* C *f* in *f*. Through the points *f*, C, draw the line *f*C, and it will be the perpendicular required.

Prob. 3. From a given point *f*, to let fall a perpendicular upon a given line A B.

From the point *f*, with any radius, describe the arc *d e*, cutting A B in *e* and *d*. From the points *e d*, with the same or any other radius, describe two arcs cutting each other in *g*. Through the points *f* and *g*, draw the line *f g*; and *f* C will be the perpendicular required.

Prob. 4. To make an angle equal to another angle which is given, as *a* B *b*.

From the point B, with any radius, describe the arc *a b*, cutting the legs B *a*, B *b*, in the points *a* and *b*. Draw the line D *e*, and from the point D, with the same radius as before, describe the arc *e f*, cutting D *e* in *e*. Take the distance *b a*, and apply it to the arc *ef*, from *e* to *f*. Lastly, through the points, D, *f*, draw the line D*f*, and the angle *e* D*f* will be equal to the angle *b* B *a*, as was required.

Prob. 5. To divide a given angle, A B C, into two equal angles.

From the point B, with any radius, describe the arc A C. From A and C with the same, or any other radius, describe arcs cutting each in *d*. Draw the line B *d*, and it will bisect the angle A B C, as was required.

Prob. 6. To lay down an angle of any number of degrees.

There are various methods of doing this. One is by the use of an instrument called a *protractor*, which is a semicircle of brass having its circumference divided into degrees. Let A B be a given line; and let it be required to draw from the angular point A, a line making with A B any number of degrees, suppose 20. Lay the straight side of the protractor along the line AB, and count 20° from the end B of the semicircle; at C, which is 20° from B, make a mark; then, removing the protractor, draw the line A C, which makes with A B the angle required.

Or, it may be done by a divided line, usually drawn upon scales, called a *line of chords*. Take 60° from the line of chords in the compasses; and setting one at the angular point B, *Prob.* 4, with that opening as a radius, describe an arch, as *a b*: then take the number of degrees you intend the angle to be of, and set it from *b* to *a*, then is *a* B *b*, the angle required.

Prob. 7. Through a given point C, to draw a line parallel to a given line A B.

Case 1. Take any point *d*, in A B; upon *d* and C, with the distance C *d*, describe two arcs, *e* C, and *d f*, cutting the line A B in *e* and *d*. Make *d f* equal to *e* C; through C and *f* draw C *f*, and it will be the line required.

Case 2. When the parallel is to be at a given distance from A B. From any two points, *c* and *d*, in the line A B, with a radius equal to the given distance, describe the arcs *e* and *f*: draw the line C B to touch those arcs without cutting them, and it will be parallel to A B, as was required.

Prob. 8. To divide a given line A B into any proposed number of equal parts.

From A, one end of the line, draw A *c*, making any angle with A B; and from B, the other end, draw B *d*, making the angle A B *d* equal to B A *c*. In each of these lines A *c*, B *d*, beginning at A and B, set off as many equal parts of any length as A B is to be divided into. Join the points C 5, 46, 37, &c., and A B will be divided as required.

Prob. 9. To find the centre of a given circle, that is, of any one already described. Draw any chord A B, and bisect it with the perpendicular C D. Bisect C D with the diameter E F, and the intersection O will be the centre required.

Prob. 10. To draw a tangent to a given circle that shall pass through a given point, A.

From the centre O, draw the radius O A. Through the point A, draw D E perpendicular to O A; and it will be the tangent required.

Prob. 11. To draw a tangent to a circle, or any segment of a circle A B C, through a given point B, without making use of the centre of the circle.

Take any two equal divisions upon the circle from the given point B, towards *d* and *e*, and draw the chord *e* B. Upon B, as a centre with the distance B *d*, describe the arc *f d g*, cutting the chord *e* B in *f*. Make *d g* equal to *d f*; through *g* draw *g* B, and it will be the tangent required.

Prob. 12. Given three points, A, B, C. not in a straight line, to describe a circle that shall pass through them.

Bisect the lines A B, B C, by the perpendiculars *a b*, *b a*, meeting at *d*. Upon *d*, with the distance *d* A, *d* B, or *d* C, describe A B C, and it will be the required circle.

Prob. 13. To describe the segment of a circle, of any length A B, and any height C D.

Bisect A B by the perpendicular D *g*, cutting A B in *c*. From *c* make *c* D on the perpendicular equal to C D. Draw A D, and bisect it by a perpendicular *e f*, cutting D *g* in *g*. Upon *g* the centre, describe A D B, and it will be the required segment.

Prob. 14. To describe the segment of a circle by means of two rulers, to any length A B, and perpendicular height C D in the middle of A B, without making use of the centre.

Place the rulers to the height at C; bring the edges close to A and B; fix them together at C, and put another piece across them to keep them fast. Put in pins at A and B, then move the rulers round these pins, holding a pencil at the angular point C, which will describe the segment.

Prob. 15. In any given triangle to inscribe a circle. Bisect any two angles A and C, with the lines A D and C D C. From D the point of intersection, let fall the perpendicular D E; it will be the radius of the circle required.

Prob. 16. In a given square, to describe a regular octagon.

Draw the diagonals A C and B D, intersecting at *e*. Upon the points A, B, C, D, as centres, with a radius *e* C, describe the arcs *h e l*, *k e n*, *m e g*, *f e i*. Join *f n*, *m h*, *k i*, *l g*, and it will be the required octagon.

Prob. 17. In a given circle, to describe any regular polygon.

Divide the circumference into as many parts as there are sides in the polygon to be drawn, and join the points of division.

Prob. 18. Upon a given line A B, to construct an equilateral triangle.

Upon the points A, and B, with a radius equal to A B, describe arches cutting each other at C. Draw A C and B C, and A B C will be the triangle required.

Prob. 19. To make a triangle, whose sides shall be equal to three given lines, D, E, F, any two of them being greater than the third.

Draw A B equal to the line D. Upon A, with the radius F, describe an arc C D. Upon B, with the radius E, describe another arc intersecting the former at C. Draw A C and C B, and A B C will be the triangle required.

Prob. 20. To make a trapezium equal and similar to a given trapezium A B C D.

Divide the given trapezium A B C D into two triangles by the diagonal D B. Make E F equal to A B; upon E F construct the triangle E F H, whose sides shall be respectively equal to those of the triangle A B D by the last problem. Upon H F, which is equal to D B, construct the triangle H F G, whose sides are respectively equal to D B C; then E F G H will be the trapezium required.

By the help of this problem any plan may be copied; as every figure, however irregular, may be divided into triangles. Upon this the practice of land-surveying and making plans of estates is founded.

Prob. 21. To make a square equal to two given squares. Make the sides D E and D F of the two given squares A and B; from the sides of a right-angled triangle F D E; draw the hypothenuse F E; on it describe the square E F G H, and it will be the square required.

Prob. 22. Two right lines A B, C D, being given, to find a third proportional. Make an angle H E I at pleasure; from E make E F equal to A B, and E G equal to C D: join F G. Make E I equal to E F, and draw H I parallel to F G; then E H will be the third proportional required; that is, E F : E G : : E H : E I, or A B : C D : : C D : E I.

Prob. 23. Three lines being given, to find a fourth proportional. Make the angle H G I at pleasure; from G make G H equal to A B, G I equal to C D, and join H I. Make G K equal to E F; draw K L through K, parallel to H I; then G L will be the fourth proportional required; that is, G H : G I : : G K : G L, or A B : C D : : E F : G L.

Prob. 24. To divide a given line A B in the same proportion as another C D is divided.

Make any angle K H I, and make H I equal to A B; then apply the several divisions of C D from H to K, and join K I. Draw the lines *h e*, *i f*, *k g*, parallel to I K; and the line H I will be divided in *e*, *f*, *g*, as was required.

Prob. 25. Between two given lines A B and C D, to find a mean proportional.

Draw the right line E G, in which make E F equal to A B, and F G equal to C D. Bisect E G in H, and with H E or H G, as radius, describe the semicircle E I G. From F draw F I perpendicular to E G, cutting the circle in I; and I F will be the mean proportional required.

Prob. 26. To describe an ellipsis.

If two pins are fixed at the points E and F, a string put about them, and the ends tied together at C; the point C being moved round, keeping the string stretched, will describe an ellipsis.

The points E and F, where the pins were fixed, are called the *foci.*

The line A B passing through the foci, is called the *transverse axis:*

The point G bisecting the tranverse axis, is the *centre* of the ellipsis.

The line C D crossing this centre at right-angles to the tranverse axis, is the *conjugate axis.*

The *latus rectum* is a right line passing through the focus at F, at right angles to the transverse axis terminated by the curve: this is also called the *parameter.*

A *diameter* is any line passing through the centre, and terminated by the curve.

A *conjugate diameter* to another diameter is a line drawn through the centre, parallel to a tangent at the extreme of the other diameter, and terminated by the curve.

A *double ordinate* is a line drawn through any diameter parallel to a tangent, at the extreme of that diameter terminated by the curve.

The transverse axis A B, and conjugate axis C D, of any ellipsis, being given, to find the two foci, and from thence to describe the ellipsis.

Take the semi-transverse A E, or E B, and from C as a centre, describe an arc cutting A B at F and G; these are the foci. Fix pins in these points; a string being stretched about the points F, C, G, the ellipsis is described as above.

Prob. 27. The same being given, to describe an ellipsis by a *trammel.*

The trammel is an instrument consisting of two rulers fixed at right-angles to each other, with a groove in each. A rod with two moveable nuts works in this groove; and, by means of a pencil fixed in the end of the rod, describes the curve. The operation is as follows:

Let the distance of the first pin at B, from the pencil at A, be equal to half the shortest axis; and the distance of the second pin at C, from A, to half the longest axis; the pins being put in the grooves, move the pencil at A, which will describe the ellipsis.

Prob. 28. To draw a figure approaching to an ellipsis with a compass to any length A B, and width C D.

Draw B P parallel and equal to E C, and bisect it at 1; then draw 1 C and P D, cutting each other at K; bisect K C by a perpendicular, meeting C D in O; and on O, with the radius O C, describe the quadrant C G Q.

Through Q and A, draw Q G, cutting the quadrant at G; then draw G O, cutting A B at M; make E L equal to E M, also E N equal to E O. From N, through M and L draw N H and N I; then M, L, N, O, are the four centres by which the four quarters of the figure are drawn.

It must be observed, that this is not a true ellipsis, but only an approximation to it; for it is impossible to draw a perfect ellipsis by means of compasses, which can only describe parts of circles. The curve of an ellipsis differs essentially from that of a circle in every part; and no portions of circles put together can ever form an ellipsis. But by this means a figure may be drawn, which approaches nearly to an ellipsis, and, therefore, may be often substituted for it when a trammel cannot be had, or when the ellipsis is too small to be drawn by it. At the joining of the portions of circles in this operation, the defect is perceivable; and the best way is not to join them quite, and to help the curve by hand.

Prob. 29. An ellipsis, A C D B, being given, to find the transverse and conjugate axes.

Draw any two parallel lines, A B and C D, cutting the ellipsis at the points A, B, C, D; bisect them in *e* and *f*. Through *e* and *f*, draw G H, cutting the ellipsis at G and H; bisect G H at I; and it will give the centre.

Upon I, with any radius, describe a circle, cutting the ellipsis in the four points *k*, *l*, *m*, *n*; join *k*, *l*, and *m*, *n*; bisect *k l*, or *m n*, at *o* or *p*. Through the points *o*, I, or I, *p*, draw Q R, cutting the ellipsis at Q and R; then Q R will be the transverse axis. Through I draw T S, parallel to *k l*, cutting the ellipsis at T and S; and T S will be the conjugate axis.

Prob. 30. To describe an ellipsis similar to a given one A D B C, to any given length I K, or to a given width M L.

Let A B and C D be the two axes of the given ellipsis. Through the points of contact A, D, B, C, complete the rectangle G E H F; draw the diagonals E F and G H: they will pass through the centre at R. Through I and K draw P N and O Q parallel to C D, cutting the diagonals E F and G H, at P, N, Q, O. Join P O and N Q, cutting C D at L and M; then I K is the transverse, and M L the conjugate axis of an ellipsis, that will be similar to the given ellipsis A D B C, which may be described by some of the foregoing methods.

Prob. 31. To describe a parabola. If a thread equal in length to B C, be fixed at C, the end of a square A B C, and the other end be fixed at F; and if the side A B of the square be moved along the line A D; and if the point E be always kept close to the edge B C of the square, keeping the string tight, the point or pin E will describe a curve E G I H, called a *parabola.*

The *focus* of the parabola is the fixed point F, about which the string revolves.

The *directrix* is the line A D, which the side of the square moves along.

The *axis* is the line L K, drawn through the focus F, perpendicular to the directrix.

The *vertex* is the point I, where the line L K cuts the curve.

The *latus rectum,* or *parameter,* is the line G H passing through the focus F, at right-angles to the axis I K, and terminated by the curve.

The *diameter* is any line M N, drawn parallel to the axis I K.

A *double ordinate* is a right line R S, drawn parallel to a tangent at M, the extreme of the diameter M N, terminated by the curve.

The *abscissa* is that part of a diameter contained between the curve and its ordinate, as M N.

Prob. 32. To describe a *parabola,* by finding points in the curve; the axis A B, or any diameter being given, and a double ordinate C D.

Through A draw E F parallel to C D; through C and D draw D F and C E parallel to A B, cutting E F at E and F. Divide B C and B D, each into any number of equal parts, as four; likewise divide C E and D F into the same number of equal parts. Through the points 1, 2, 3, &c. in C D, draw the lines 1 *a*, 2 *b*, 3 *c*, &c. parallel to A B; also through the points 1, 2, 3, in C E and D F, draw the lines 1 A, 2 A, 3 A, cutting the parallel lines at the points *a*, *b*, *c*; then the points *a*, *b*, *c*, are in the curve of the parabola.

Prob. 33. To describe an *hyperbola.*

If B and C are two fixed points, and a rule A B be made moveable about the point B, a string A D C being tied to the other end of the ruler, and to the point C; and if the point A be moved round the centre B, towards G, the angle D of the string A D C, by keeping it always tight and close to the edge of the rule A B, will describe a curve D H G, called an *hyperbola.*

If the end of the ruler at B were made moveable about the point C, the string being tied from the end of the ruler A to B, and a curve being described after the same manner, is called an *opposite hyperbola.*

The *foci* are the two points B and C, about which the ruler and string revolves.

The *transverse axis* is the line I H, terminated by the two curves passing through the foci, if continued.

The *centre* is the point M, in the middle of the transverse axis I H.

The *conjugate axis* is the line N O, passing through the centre M, and terminated by a circle from H, whose radius is M C, at N and O.

A *diameter* is any line V W, drawn through the centre M, and terminated by the opposite curves.

A *conjugate diameter to another*, is a line drawn through the centre, parallel to a tangent with either of the curves, at the extreme of the other diameter terminated by the curves.

Abscissa is when any diameter is continued within the curve, terminated by a double ordinate and the curve; then the part within is called the abscissa.

Double ordinate is a line drawn through any diameter parallel to its conjugate, and terminated by the curve.

Parameter, or *latus rectum*, is a line drawn through the focus, perpendicular to the transverse axis, and terminated by the curve.

Prob. 34. To describe an hyperbola by finding points in the curve, having the diameter or axis A B, its abscissa B G, and double ordinate D C.

Through G draw E F, parallel to C D; from C and D draw C E and D F, parallel to B G, cutting E F in E and F. Divide C B and B D, each into any number of equal parts, as four; through the points of division, 1, 2, 3, draw lines to A. Likewise divide E C and D F into the same number of equal parts, viz. four; from the divisions on C E and D F, draw lines to G; a curve being drawn through the intersections at G, *a*, *b*, &c. will be the hyperbola required.

PERSPECTIVE.

Perspective is the art of drawing upon a plane surface the outlines of objects, so as to give the same representations to the eye that the objects themselves do in nature.

This art is of the utmost importance in drawing, and its study cannot be dispensed with by those who wish to make any proficiency in this art. Some knowledge of it ought to be acquired, previous to the study of every branch of drawing, whether that of the figure, landscape, flowers, &c.; for though its utility may not appear equally evident in all these, yet there are many cases in each, where it is of indispensable necessity; and an acquaintance with it will save the student the trouble of much wrong thinking, and will enable him to avoid many errors which he otherwise must necessarily fall into.

It is true, that many people learn to draw without studying perspective, and too many of those whose profession it is to teach this useful branch of education, do not sufficiently recommend to their pupils to learn the principles of this science. The reason of this it is not difficult to point out. The study of perspective, like that of geometry, has in itself but few charms, and it is only by being well convinced, that without it we can never hope to arrive at excellence, and by experiencing how much it accelerates and assists us in our practice of drawing, that we can with patience and resolution go through studies that certainly appear to most people dry and unentertaining. Unfortunately, from this circumstance, and from the abstruse and obscure manner in which it is treated off by the generality of writers on the subject, few will take the trouble of making themselves acquainted with a science so necessary.

But though the understanding perspective *thoroughly*, certainly does require considerable geometrical knowledge, added to great patience and persevering investigation, yet so much as would enable those who draw to avoid making any very glaring blunders, and render their study of drawing much more pleasant and easy, is so far from being difficult, that it is astonishing any one should hesitate a moment about acquiring it.

Some part of the blame may, however, be fairly laid to the want of a treatise on perspective, of an easy and popular kind, such as might suit those who have had no opportunities of acquiring a knowledge of geometry. It would be in vain to endeavour to supply this deficiency properly in a work of so limited a nature, and which embraces so many subjects as the present; yet though our plan will not permit us to treat of it so fully as it deserves, we shall lay down, as concisely as possible, a few of its principal rules, the understanding of which will be found useful to beginners in the art of drawing.

Explanation of the principal Terms used in Perspective.

The *perspective plane* is the surface of the picture itself, which may be imagined to be a plane of glass placed upright between the spectator and the objects to be drawn. Then, if lines or rays be supposed to come from every part of the objects to the spectator's eye, when viewing them through the glass, they would cut the plane in certain points; and if these points were connected by lines, they would give the perspective representation. It is upon this simple idea that all the rules of perspective are founded: they are so many methods of finding out the above-mentioned points; and when the light, shadow, and colour, are added, the whole constitutes a picture exactly resembling the original.

Visual rays are the rays of light which come from the different parts of the objects to our eyes.

Point of sight is the spectator's eye. This has been erroneously confounded with the *centre of the picture*, as will be seen afterwards.

What is called an *original line*, is any line in Nature, or in the objects themselves, which are to be drawn in perspective.

An *original plane* is any surface or plane of the objects to be represented.

If we suppose a line to proceed from the eye, parallel to any line in the objects we are viewing, and to continue till it arrive at the picture or perspective plane, the point where it would touch the plane is called the *vanishing point* of the line.

All lines that are in Nature parallel to each other have the same vanishing points. The reason of this will be easily seen, if the reader considers the method of finding the vanishing point of an original line just mentioned; for the same line which would find the vanishing point of one, will do for them all, and form only one point.

If we could suppose a plane or surface to proceed from the eye of the spectator, in a direction parallel to any side of an object which we view through the plane of glass, and if it continue till it arrive at the glass, the line which it would form by contact with the glass, is called a *vanishing line;* and it is the vanishing line of the side of the object which the supposed plane was parallel to.

In every *picture* or *perspective plane*, there is a point, where a line drawn from the eye perpendicular to the picture, would touch it; this point is called the *centre of the picture*, and is the same which is often called in old books on perspective, the *point of sight*. But this is a wrong term for it;

the point of sight, strictly speaking, being in the spectator's eye, and consequently, not any point in the picture. Although, from its name, we should expect to find it always in the middle of the representation, yet this is by no means the case, for sometimes it is near one of the sides, particularly in what is called parallel perspective; though generally in oblique perspective, it is in the middle of the picture. And here it should be observed, that, strictly and properly, it should always be in the middle of the picture, when circumstances of convenience will admit of it; for it is that point which the spectator is supposed to look full against, or which is exactly opposite to his eye when he views a picture, and surely the best way to see a picture, is to look directly against the middle of it. However, in many kinds of perspective drawings, it is not convenient, on account of room, to have this point in the middle, as may easily be imagined by considering Plate 6. Fig. 1., where G is the centre of the picture.

It will be easily conceived, from the description of vanishing points, and the centre of the picture, that this last must be the vanishing point of all lines that are in Nature perpendicular to the picture.

If a plane be supposed to proceed from the eye, as before, parallel to the floor or level ground till it arrives at the picture, the line where it meets it is called the vanishing line of the horizon, or *horizontal line*. This line is of great importance in perspective: the centre of the picture is always somewhere in this line. Its height is necessarily regulated by the height of the eye from the ground; in landscapes, and views of places, it is generally kept one-third of the height of the picture from the bottom, though this rule is not always adhered to; for when we stand upon high ground, the horizontal line rises in proportion. Suppose the view to be taken on level ground, the head of a man represented standing on the ground, would come to this line, and that whether the man be near or far off; that is, wherever his feet are, his head must always come to the horizontal line, if he be standing upright on the ground.

Distance of the picture means the supposed distance of the eye from the centre of the perspective plane or picture.

This distance may be chosen at pleasure; but a judicious choice of it is very important, for the variation of this distance affects every perspective representation, so as to render them either pleasing or distorted. Long distances, in general, give the best representation; but they are not always convenient, or to be attained. Experience alone can direct a proper medium.

Parallel perspective is where the picture is supposed to be so situated, as to be parallel to the side of the principal object in the picture, as a building, for instance. Then the lines on those sides of the building that are parallel to each other continue parallel on the picture, and do not vanish into any point; while the lines at right angles to the former vanish into the centre of the picture. This will be exemplified in Plate 6. Fig. 1.

The picture being supposed to stand parallel to the side of the house A B C D, the lines A B, D C, which in Nature are parallel to each other, must be made parallel in the perspective representation. But the lines B E, C F, which in Nature are at right angles to A B, and D C, and, consequently, also to the picture, tend towards a point; and this point G, towards which they tend, is the centre of the picture.

Oblique perspective is when the plane of the picture is supposed to stand oblique to the sides of the objects represented; in which case the representations of the lines upon those sides will not be parallel among themselves, but will tend towards their vanishing point. This kind of perspective is shown in Plate 7. Fig. 1.

A *bird's-eye view* is a view supposed to be taken in the air, looking down upon the object; and differs from the usual way of drawing perspective views, only in supposing the horizontal line to be raised much higher.

When an object is to be drawn in perspective, all its parts must be measured, so that we may be able to lay them down from a scale of equal parts.

Having determined whether it is to be parallel or oblique perspective, the first thing to be drawn is the horizontal line, which is to be put parallel to the bottom of the drawing, and as high above it as the height of a man's head, as H G, Plate 6. Fig. 1., which is five feet six inches above the bottom of the house. Next determine on the centre of the picture G, which must be placed so as to leave convenient room for the representation. Fix on C the nearest corner of the object, and draw the perpendicular C B: lay off C D equal to the length of the building, and draw D A and A B. From C, the nearest corner, draw C G, to the centre of the picture. C G now contains the line which represents the bottom of the end of the house; but this is an *indefinite* representation, of which we do not yet know the exact length. The method of determining this is as follows: Continue the line D C to I, and make C I equal to the width of the house. From G, the centre of the picture, lay off G K equal to the distance of the picture, the choosing of which must be regulated by taste. Draw I K, cutting C G in F; then is C F the exact width of the house in perspective, which was equal to C I. To find the middle of this end of the house, you cannot divide it by your compasses, because the farthest half will appear less than the nearer; but if you divide C I into two equal parts in L, and draw L K, it will cut C F into two equal parts perspectively. Or it may be found more simply thus: Having drawn the lines B E and C F to the centre of the picture, draw the diagonals E C, B F crossing each other in M, and raise the perpendicular M N, which is in the middle of the gable-end.

To find the height of the gable, lay its actual height above B E, upon the corner line B C continued, as B O, and draw O G; this crossing the perpendicular M N, gives N the point of the gable. The top of the chimney must be drawn in the same manner, by laying its real height, taken from a scale on O P, and drawing P G, lay off L *m* and L *n*, each equal to half the width, and draw from these points to the distance point *k*; this will cut the bottom of the house C F, in the points *o* and *p*; from these draw perpendiculars, which will give the perspective width of the chimney. To obtain its thickness, lay off P Q equal to its thickness, and draw Q G; then drawing from *a* the line *a b*, you obtain the exact width of the chimney. From *b* draw *b c*, and from *d* draw *d c*. The other end of the gable may be drawn by two different methods. The first is by supposing the front of the house transparent, and drawing the other end as if seen through it, in the same manner as the end we have described, by laying its width from D to R, and drawing to the distance-point K. By raising the perpendicular in the middle, you will meet the ridge-line from the other gable in *d*. The other method is as follows: Through the centre of the picture G draw the line S T, upwards, and downwards, and perpendicular to the horizontal line. Then continue the line of the roof B *d* till it meet S T in S. From A draw A S, which will give the other gable, and S will be the vanishing point for all lines parallel to B *d* and A *d*; if N E be continued in like manner, it will give T for its vanishing point. The doors and windows on the side A B C D are laid down from a scale, because that side, being parallel to the picture, does not vary from its geometrical delineation, except shewing the thickness of the reveals, or edges of the doors and windows. If there had been any windows in the side B E F C, they would be drawn in perspective by the same method that was used for finding the width of the house and the middle of the end; viz. by laying off the actual dimensions from C upon C I, and drawing from these points to the distance-point K, which would transfer these divisions to the bottom of the house C F, and then perpendiculars might be drawn upwards.

This practice is farther explained by the following rule.

To divide a line in perspective which is parallel to the horizon, and which tends to a vanishing point, into any number of equal parts; or to divide it in any required proportion.

Let A B be the line going to its vanishing-point C (Fig 2.); and first let it be required to divide that line into six equal parts. Let C D be the horizontal line, and AE the ground-line drawn parallel to it. Lay off, at pleasure, CD for the distance of the picture, if C be the centre of the picture. Draw a line from D, touching the end B of the line to be divided: draw DBE, cutting the ground-line in E. Then AE represents the actual dimensions of the line AB, which is seen in perspective. (Here it may be observed, that this gives a rule also for finding the real length of any line which tends to a vanishing-point.) Divide AE into the same number of equal parts into which you proposed to divide the given line AB; as A1, 12, 23, &c. Then from these different divisions draw lines to D, cutting the line AB in *a*, *b*, *c*, *d*, &c., which will represent the required number of equal parts, but diminishing in size as they are farther removed from the eye. If it be wished to divide the line AB into any number of unequal parts, or to lay off doors, windows, &c. upon it, the line AE, found as before, must be divided in the required proportion; and lines drawn from those to D will give the required divisions on AB, from which perpendiculars may be drawn for the doors, windows, &c.

To draw a circle in perspective.

The perspective representation of every circle is a regular ellipsis, when the eye is without the circle, which may be demonstrated, by considering that the rays from the circumference of the circle to the eye, form an *oblique cone*. But it is well known to those who are acquainted with conic sections, that every section of a cone, whether right or oblique is a true ellipsis, except in one case only, which is, when the section is taken sub-contrary to its base, a situation which happens so rarely in drawings, that it may be disregarded altogether, and the section of a cone, or the perspective of a circle, in all cases considered as a perfect ellipsis.

The most correct and easy method of drawing an ellipsis is to find the transverse and conjugate axes, and then to complete the curve by a trammel, or by hand. But as it is very difficult to find the transverse and conjugate axes of the ellipses which are the perspective representations of circles, recourse is generally had to another method of obtaining the curve. The circle is circumscribed by a square, as K L M N, in Fig. 3., and the diagonals and the lines across the centre, and parallel to the sides, are drawn; also the lines, *al*, *cd*, are drawn parallel to the sides, through the points where the circle is cut by the diagonals. This square, with all these lines drawn across it, is now put in perspective as follows: Draw A B for the horizontal line, and fix B for the centre of the picture, and A B for the distance of the picture. Make D C equal to the width of the square, and draw C B, D B; draw C A to the distance-point A, cutting off D G equal to the depth of the square; then draw G F, parallel to D C, which completes the perspective of the square; also draw the diagonal D F. Take now the distances M *a*, *c* N; and transfer them to D *x*, *o* C; from these points *x* and *o* draw lines to the vanishing point B, cutting the diagonals of the square. The points in this reticulated square in perspective, which correspond to those in the square K L M N, where the circle passes through, must now be observed, and a curve traced through them with a steady hand: it will be the perspective required. Even in this process, it is of considerable use to know that the curve you are tracing is a regular ellipsis; for though you cannot easily ascertain the axes *exactly*, yet you may *very nearly*; and the eye very soon discovers whether the curve which has been drawn, be that of a regular ellipsis or not.

Upon the same principle the row of arches (Fig. 4.) is drawn. The width of the arches and piers is obtained in the same manner as was shown in Fig. 2.; viz. by laying their dimensions upon the ground-line A B, and drawing lines to the distance-point. The curves of the arches are then found, by drawing the lines which correspond to those in half the square, Fig. 3., in the same manner as described above for the circle.

Fig. 5. shows the appearance of circles drawn upon a cylinder, when H I is the horizontal line. The circle drawn on the cylinder at that place is seen exactly edgeways, and appears only as a straight line; that next above it is seen a little underneath; the next still more; and so on, as they rise higher, appearing like so many ellipses of the same transverse diameter, but whose conjugate diameters continually increase in length as they rise above the horizontal line. On the contrary, you see the under sides of the circles drawn below the horizontal lines; but they observe the same law, being so many ellipses whose conjugate diameters vary in the same proportion. A little reflection on this simple example will enable those who draw to avoid many ridiculous mistakes which are sometimes committed, such as showing the two ends of a cask, or the top and bottom of a cylinder, at the same time.

Pl. 7. Fig. 1. shows the method of drawing a building, or other object, in oblique perspective. A B is the horizontal line, and C D the ground-line parallel to it as before. Here neither of the sides of the house is parallel to the picture, but each goes to its respective vanishing point. Having fixed on the nearest corner E, draw E B, at pleasure, for one side, and choose any point F for the centre of the picture; then, to find the other side, lay off F G equal to the distance of the picture, which, as before, depends upon taste only; draw B G and G A perpendicular to B G, cutting the horizontal line in A, the other vanishing point. Draw now E A for the other side. To cut off the several widths of the two sides of the house, which as yet are only drawn to an indefinite extent, two distance-points must be laid down, viz. one for each vanishing point. To do this, extend the compass from B to G, and lay the distance taken in it from B to H, which will give H for the distance-point of B, and which is to cut off all the divisions on the side E B. Also extend the compasses from A G, and lay down A I. I is the distance-point of A, and is used for transferring all divisions upon the side E A, from the ground-line C E. These points and lines being adjusted, the process is not much different from parallel perspective; only here, equal divisions on *each* side of the building, as doors, windows, diminish as they recede, in the same way as on the side B E F C, Pl. 6. Fig. 1. Take the *real* length of the side E L, from the same scale used for laying down the horizontal linė, and lay it down on the ground-line from E to C, and draw C I, cutting off E L for the *perspective* length of the building. For the other side of the house, lay its width down in the same manner, from E to D, and draw D H, cutting off E N for the perspective width. Raise the perpendiculars E M, L K, and N O, for the three angles of the house. Lay the height of the building upon the corner that comes to the ground-line, as E M, and draw M K and M O to their several vanishing points. Also lay all the heights of the doors and windows, and other divisons, upon E M, and draw them to the vanishing points A and B.

To lay down the widths of the doors and windows, put their actual widths upon C E, and draw from them to the distance-point I, which cuts off all divisions upon the side L E, and then raise the perpendiculars. The gable-end is found exactly in the same manner as was described in Pl. 6. only taking care to use the proper distance-point H. The manner of finding the width of the chimney is different. Lay off *b a* for the height of the chimney above the top of the gable, and draw *a c* parallel to the horizontal line; then put *a c* equal to the actual thickness of the chimney, and draw *a d* to the vanishing point A; draw also *c d* to the distance-point I, cutting off *a d* in *d*: then having drawn *e f* from the nearest corner of the chimney, which was found as in Pl. 6. Fig. 1. Draw *d f* to the vanishing point B, cutting off *e f* for the exact perspective width.

Fig. 2. represents the method of finding the perspective of a circle in *oblique* perspective. A B is the horizontal line, C the centre of the picture, and D, E, the distance-points. The process is exactly the same as that just described, the several divisions of the reticulated square in Pl. 6. Fig. 3. being laid upon the ground-line F G, and from these lines are drawn to the distance-points. The perspective of the square is then drawn with all the lines across it, and the curve traced through the different points.

By drawing these examples frequently over, to large scale, and reflecting upon them with attention, the student will become familiar with their use; and as they include the cases which most frequently occur, he will find great benefit from the knowledge of them.

Drawing the Figure.

The study of the human figure has always been considered by artists as the most important part of the art. It is the most difficult, and is by many considered as contributing the most of any to general improvement; though there are some who carry this idea to too great an extent, saying, that a person who can draw the human figure well can draw every thing besides. But this, it is well known, is not the case; there being many artists who can draw the figure very well who cannot draw landscape nor architecture. To draw any thing well requires a particular study. The study of the figure, however, includes all the finest principles of the art; and when the eye of the student has been accustomed to copy faithfully all the minute circumstances which constitute the character of a figure, and to attend to the innumerable beauties and graceful forms which it presents, he will be better qualified to pursue with advantage every other branch of the fine arts.

In learning to draw the human figure, it is necessary to begin with each of the parts separately, and after sufficient practice in that way, to proceed to put them together in the complete figure.

The head being the most important part of the human body, it should be studied first. For this purpose, the student should copy the best drawings he can procure of the *eye*, *mouth*, *nose*, and *ear*, separately and on a large scale; and of these, a front view, profile or side view, oblique view, &c.

The best materials for drawing these, as well as all other parts of the figure, is black chalk, or black lead; the former may be used either upon white paper, or upon middle-tint paper; and in that case, white chalk may be used for laying on the lights. Black lead is only used upon white paper. A piece of soft charcoal may be made use of for first slightly sketching in the general form, which must afterwards be gone over and corrected with the black chalk. The false lines of the black lead may be removed by the Indian rubber; but we would recommend to be as sparing as possible of this, as it is more improving to endeavour to draw every thing correct and decided at once, and not trust to the being able to erase the lines which are wrong.

The shadows may be laid on by drawing parallel curve lines, according to the situation of the part, crossing them occasionally, and softening them in with more delicate lines, where necessary.

All the parts of a human figure are composed of curved surfaces: no straight lines are ever admissible; but every line should have a graceful turn; and it is this circumstance particularly that occasions the study of the figure to give so much freedom in drawing.

Care should be taken, that no lines ever cross each other at right angles, which gives a disagreeable *net-like* appearance; neither should the crossings be too oblique, as then they are confused: a proper medium will be acquired by the study of good drawings or prints; in general, however, crossing should be avoided as much as possible.

Sometimes the shadows are rubbed in, or their edges are softened with a *stump*, which is a very expeditious way, and produces a fine effect; but it should be used with discretion, as it is better to execute the shadows in a clear and regular manner by soft lines.

Care should be taken not to make the lines harsh and hard, like those of an engraving; they should be softer and more mellow. On this account, *drawings* are much better to learn from than prints; as, by copying the latter, the student is very apt to acquire a dry and hard manner.

But we particularly caution him to avoid copying with a pen all the lines in engravings used for the shadows, which some, who have not been accustomed to see good drawings, are apt to do.

Many productions of this kind have been executed with an immensity of labour, and have been thought very fine by those who had but little knowledge of the art; yet artists, and those who are good judges, always lament to see so much patience and labour misapplied.

In copper-plate engravings, shadows are generally produced by lines: but this arises from the nature of the process; and in drawing, which is of a very different nature, there is not the same necessity for them. In general it should be observed, that the less labour there appears in any drawing the better; and that though every possible pains should be taken to make drawings or paintings excellent, yet this labour should be always disguised as much as possible, and the whole should appear as if executed with the greatest ease.

"In learning to draw, it is of more importance than is generally supposed, to copy from the finest works only. The most prejudicial quality of a model is mediocrity. The bad strike and disgust; but those that are not good, nor absolutely bad, deceive us by offering a dangerous facility. It is for this reason that engraving contributes to the progress of the arts, when it is employed on subjects that are judiciously chosen; but is too often prejudicial, by the indifferent works it multiplies without number. But let Raphael be copied by skilful engravers, let a young artist profit by his labours, and works without dignity and expression will soon become intolerable to him; he will perceive to what an elevation the excellence of the art can raise him.

"The way to avoid mediocrity, is by the study and imitation of beautiful productions; or, in want of them, of the most finished translations that have been made from them; for so we may call beautiful prints. Let a young draughtsman study the heads of Raphael, and he will not see without disgust the sordid figures of indifferent painters. But if you feed him with insipid substances, he will soon lose the taste necessary to relish great excellencies. In the one case he will advance firmly in his career: in the other he will continually totter, and even not be sensible of his own weakness."

Having copied frequently the parts of a face, he is next to proceed to the entire head; drawing first a front view, then a profile, a three-quarter, and so on; varying it in every possible direction, till he is thoroughly acquainted with the appearance of all the principal lines in every situation. In making these studies, he should be contented at first with drawing *mere outlines*, as they are by far of the most importance; and it should be remembered in general, that to make a *good outline* is always the most desirable attainment.

The student should now accompany his lessons by making observations on good *casts* and living models; but more particularly the former, as individual nature is seldom fine, and there is danger of copying what is bad, and acquiring false ideas of beauty.

By these exercises he will have acquired some facility in handling his pencil, and he will be thus prepared for the study of the whole figure. But before he can proceed to this with advantage, we would recommend to him the study of anatomy.

An artist who is not acquainted with the form and construction of the several bones which support and govern the human frame, and does not know in what manner the muscles moving those bones are fixed to them, can make nothing of what appears of them through the integuments with which they are covered; and which appearance is, however, the noblest object of the pencil. It is impossible for an artist to copy faithfully what he sees, unless he thoroughly understands it. Let him employ ever so much time and study in the attempt, it cannot but be attended with many and great mistakes; just as it must happen to a man who undertakes to copy something in a language which he does not understand, or to translate into his own what has been written in another, on a subject with which he is not acquainted.

But it is not necessary for him to study anatomy as a surgeon, nor to make himself acquainted with all the nerves, veins, &c. It is sufficient to study the skeleton, and the muscles which cover them, and of these, he should most particularly make himself familiar with those muscles which most frequently appear and come into action.

For this purpose, he should procure plaster casts of the anatomy of the human body, and consult treatises written upon the subject; and if he have opportunity, it will be proper afterwards to attend discussions and lectures on anatomy.

He should also use every possible opportunity of making observations on the actions of the muscles in nature.

Being thus thoroughly prepared, he will be enabled to draw the human figure with great advantage, and he will make a more rapid progress than he could have done without these previous studies.

Symmetry, or *proportion*, will be best learned by copying after the antique statues, of which plaster casts may be easily procured. Nature, which in the formation of every species seems to have aimed at the last degree of perfection, does not appear to have been equally solicitous in the production of individuals. Parts of individuals are frequently as beautiful as possible, but a complete whole is never to be met with.

The practice of the ancient Greek statuaries was to select from various individuals the most beautiful parts, and by combining them to produce figures more perfectly beautiful than nature ever presented.

Till the student has thus imbibed a proper relish for beautiful proportions, and been well grounded in their principles, he should not proceed to draw from living models.

In drawing from plaster casts, a good deal depends upon choosing a proper view, and placing the model properly with regard to the light, which should always come in obliquely from above, as it generally does in the daytime. If a candle be used, it should be so high as to cast the light downwards upon the model. The light should only come from one part, as cross lights will distract and spoil the shadows.

After the student has with indefatigable labour and persevering zeal gone through all these studies, and acquired a facility of drawing the human figure in every possible situation, and under every variety of form and circumstance, a great deal remains for him still to do, before he can be considered as an artist. He has as yet conquered only the mechanical difficulties; but his mind must be cultivated, and he has all the higher and more refined parts of his art to study.

It is the business and duty of the naturalist and historian to draw objects as they find them, and represent them with all those imperfections and blemishes to which, as individuals, they are subject. But an ideal painter, and such alone is a true painter, resembles the poet; his creative fancy soars above common nature, and he represents objects endued with all that perfection which belongs to the species, but which is rarely found in the individual.

A good choice of subjects for the exercise of his pencil is now to be considered. For this purpose, he should enrich his mind with a great variety of knowledge: historians and poets should be his constant companions; and he should make himself acquainted with the customs and manners of ancient as well as modern nations.

His *invention* should now be continually exercised, and free scope should be given to the wildest sallies of his imagination, which, however, should never exceed the bounds of probability.

" It is indisputably evident," says Sir J. Reynolds, " that a great part of every man's life must be employed in collecting materials for the exercise of genius. Invention, strictly speaking, is little more than a new combination of those images which have been previously gathered and deposited in the memory. Nothing can come of nothing; he who has laid up no materials, can produce no combination.

"He should study the works of former artists, learn what subjects they have painted, and how they have treated them. A student unacquainted with the attempts of former adventurers, is always apt to over-rate his own abilities, to mistake the most trifling excursions for discoveries of moment, and every coast new to him, for a newly-discovered country.

"On whom, however, can he rely, or who shall show him the path that leads to excellence? The answer is obvious: those great masters who have travelled the same road with success are the most likely to conduct others. The works of those who have stood the test of ages, have a claim to that respect and veneration to which no modern can pretend. The duration and stability of their fame is sufficient to evince that it has not been suspended upon the slender thread of fashion and caprice, but bound to the human heart by every tie of sympathetic approbation.

"But though these masters should be studied, they should not be servilely followed. The student, instead of treading in their footsteps, should only keep the same road. He should endeavour to invent on their principles and way of thinking; he should possess himself with their spirit; he should consider how they would treat his subject, and should work himself into a belief that they are to see and criticise his picture when completed. Every attempt of this kind will rouse his powers."

Whenever a story is related, every man forms a picture in his mind of the action and the expression.

of the persons employed. The power of representing this mental picture on canvass is what we call invention in a painter.

In the conception of this ideal picture, all the little circumstances should be contrived in such a manner, that they shall strike the spectator no more than they did himself in his conception of the story. Thus there must be a principal object, which should receive the principal mass of light; and though a second and third group may be added, and a second and third mass of light, yet they should be all kept so subordinate, that they do not come in competition with the principal.

In the *design* or *composition* of a picture, *simplicity* is of the first importance. The story should be *distinctly* told, and nothing should be introduced but what is absolutely necessary.

Among the most difficult and important of the higher branches of the art, is the *expressions of the passions.*

It is not enough for a painter to delineate the most exquisite forms, give them the most graceful attitudes, and compose them well together; he must express by their actions and countenances the state of their minds; they must appear to feel and to think.

Many have written, and among the rest the famous Le Brun, on the various changes that, according to various passions, happen in the muscles of the face. They observe, for example, that in fits of anger, the face reddens, the muscles of the lips puff out, the eyes sparkle; and that, on the contrary, in fits of melancholy, the eyes grow motionless and dead, the face pale, and the lips sink in. It may be of service to a painter to read them and such other remarks; but it will be of infinitely more service to study them in nature itself, from which they have been borrowed, and who exhibits them in that lively manner which neither tongue nor pen can express.

The *colouring* must be regulated by the same general principles as the composition. Gaudiness and glare ought to be studiously avoided, and a quietness and simplicity should reign through the whole work. In landscapes, distinct and unbroken colours, such as green, red, &c. are seldom or ever admissible; the tints should be always varied and broken. But in historical subjects frequently, distinct colours are employed, but they must be placed with respect to each other, so that the effect of the whole be harmonious.

The art of disposing the *drapery* makes a very considerable part of the painter's study. To make it merely natural is a mechanical operation, to which neither genius nor taste are required; whereas, it requires the nicest judgment to dispose the drapery, so that the folds have an easy communication, and gracefully follow each other with such natural negligence, as to look like the effect of chance, and at the same time show the figure under it to the utmost advantage.

In the higher style of painting, the difference in the materials of which the drapery is composed, that is, whether it is silk, linen, woollen, &c. is never remarked; it is simply drapery, and nothing more.

We have now treated, as fully as our limits will permit, of the various excellencies necessary to be acquired by an artist. It will be easily perceived, that to accomplish all these objects is by no means an easy task.

In some, an inclination to pursue the arts appears at a very early period of life, and it is often difficult to ascertain the circumstance which gave that particular impulse to the mind; though there must always be some accidental circumstance, not depending upon ourselves, that creates in us that desire.

When a boy is possessed of good talents, and has so strong a passion for the arts, that scarcely any thing can restrain him, there can be little fear of his doing well, if suffered to follow the bent of his inclination; but without this, nothing should induce him to engage in a profession of so arduous a nature, and which requires such unwearied application. He may learn to draw the correct outlines of buildings, and other regular objects, by the rules of perspective; but the forming fine pictures, so as to affect the mind, is an art not reducible to rule; and though much may be taught, yet much more will ever depend upon the mind of the artist. Here it is that the existence of a quality which distinguishes one man from another is so obvious. This has been denominated by various appellations, none of which are capable of being correctly defined. It has been called *genius*, *taste*, *soul*, *mind*, and a variety of other terms, all of which are indefinite, and prove that we know but little of our own nature.

It will be foreign to our purpose to enter into any discussion on this subject; but we shall add a passage relating to it from the lectures of the late Sir Joshua Reynolds: "There is one precept," he observes, "in which I shall be opposed only by the vain, the ignorant, and the idle. I am not afraid that I shall repeat it too often. You must have no dependence on your own genius. If you have great talents industry will improve them: if you have moderate abilities, industry will supply their deficiency. Nothing is denied to well-directed labour; nothing is to be obtained without it. Not to enter into metaphysical discussions on the nature or essence of genius, I will venture to assert, that assiduity unabated by difficulties, and a disposition eagerly directed to the object of its pursuit, will produce effects similar to those which some call the result of *natural powers*. Though a man cannot at all times, and in all places, paint or draw, yet the mind can prepare itself by laying in proper materials, at all times and in all places."

"I cannot help imagining that I see a promising young painter, equally vigilant, whether at home or abroad, in the streets or in the fields. Every object that presents itself is to him a lesson. He regards all nature with a view to his profession, and combines her beauties, or corrects her defects. He examines the countenances of men under the influence of passion, and often catches the most pleasing hints from subjects of turbulence or deformity. Even bad pictures themselves supply him with useful documents; and, as Leonardo da Vinci has observed, he improves upon the fanciful images that are sometimes seen in the fire, or are accidently sketched upon a discoloured wall."

"The artist who has his mind thus filled with ideas, and his hand made expert by practice, works with ease and readiness; whilst he who would have you believe that he is waiting for the inspirations of genius, is in reality at a loss how to begin, and is at last delivered of his monsters with difficulty and pain."

"What then," exclaims Gesner, "must be the fate of those who do not join an inflexible labour to an habitual meditation? Let the artist who despises or neglects these important means make no pretension to the recompense due to active and sensible minds. There is no reputation for him, to whom a taste for his art does not become his ruling passion; to whom the hours he employs in its cultivation are not the most delicious of his life; to whom the study of it does not constitute his real existence and his primary happiness; to whom the society of artists is not, of all others, the most pleasing; to him whose watchings, or dreams in the night, are not occupied with the ideas of his art; who in the morning does not fly with fresh transport to his painting-room. But, of all others, unhappy is he who descends to flatter the corrupt taste of the age in which he lives, who delights himself with applauded trifles, who does not labour for true glory, and the admiration of posterity. Never will he be admired by it; his name will never be repeated; his works will never fire the imagination, nor touch the hearts of those fortunate mortals who cherish the arts, who honour their favourites, and search after their works."

The Drawing of Landscapes.

Every one who wishes to learn to draw landscapes should begin by the study of perspective. This will enable him not only to understand and draw all the parts of buildings which so frequently form a principal feature in views of places, but will also give him true ideas of the method of expressing distances, the winding of roads, and a variety of particulars that are continually occurring.

Having made himself master of the principal difficulties in perspective, he should next copy some good drawings; and here it is of great importance that what he copies *first*, should be *very excellent;* for it is an absurd notion, that indifferent drawings will do to begin with, or to bring the hand in, as it is termed; but, it has been justly observed, the most likely effect these can produce will be to put the hand out.

In choosing drawings to copy for beginners, particular attention should be paid to select those where the outlines or forms of the objects are distinctly and correctly drawn, and not those in which a *good effect* only has been principally aimed at. The first thing to be studied, is to be able to express with the black-lead pencil, decidedly and truly, the forms of all sorts of objects; and till this is attained, no attempt should be made at finished drawings or pictures.

Black-lead is the most useful material for drawing the outlines of landscapes, which are best executed with this alone, and should not be gone over afterwards by the pen, which, except it be very judiciously managed, generally gives an appearance of hardness.

Indian ink alone should be used for the shadows till the student has advanced very considerably; nor till then should colours of any kind be used. Beginners are always desirous of producing pictures and making coloured drawings; but nothing is more hurtful than the practising this too early. The first thing to be learned, is to draw forms correctly; next, the mode of shadowing objects truly; then the general light and shadow of a drawing, and with this good composition. All this is best learned by using black lead, black chalk, white chalk, Indian ink, and these separately or combined, according to the taste of the student; avoiding colours till he has made considerable progress.

When colours are employed, they should be used with great caution and judgment. Nothing is so disgusting as to see coloured drawings where the reds, greens, and blues, are laid on in the most violent manner, without any regard to harmony. Those who execute such vile daubings will say, in their defence, that nothing can be greener than grass, nor bluer than the sky; but they should consider, that nature employs such a multitude of little shadows, and such a variety of different tints intermixed with her colours, that the harshness of the original colour is corrected, and the effect of the whole is very different from a raw and distinct colour laid upon white paper. Though we should have recourse to the study of nature, in preference to any master, for the study of colouring, yet it requires some judgment to know what part of nature is to be studied, and what is to be avoided; for in nature herself, there are many parts which are bad; and to copy them, would do more harm than good. The student in colouring may examine, with every possible attention, the colouring of old walls, broken and stained by time and the weather, old thatch, old tiles, rotten wood; in short, all objects which are covered with moss, stains, and tints of various kinds; there he will find all that is most perfect and harmonious in colouring. Let him copy these with every possible care, and avoid as bad all new buildings, new railing, and objects which are of a uniform decided colour. This has been the practice of all the great masters who have excelled in this captivating part of the art. In short, after learning the first principles of drawing, he cannot too soon have recourse to nature; he will obtain from her the materials for acquiring every species of excellence, in a greater degree than from the works of the first masters. The study of these, however, will greatly abridge his labour, and it should go hand in hand with drawing from nature.

The fewer colours that are used in a drawing, the better, as harmony is most easily preserved; and by the mixture of a few, every possible tint may be obtained.

It was mentioned, when treating on optics, that the sun's rays were considered by Sir Isaac Newton to be composed of seven primitive colours; but all the vast variety of tints which we see in nature may be formed by the mixture of red, blue, and yellow, in various proportions. If we had pigments of these colours perfectly pure, we should have no occasion for more than these three; but this is not the case, and therefore we are obliged to have recourse to materials of other broken tints. The colours that are found to be the most useful in drawing landscapes in water-colours, are, *lake, indigo, Prussian-blue, gamboge, light red, yellow ochre, burnt terra Sienna, burnt umber*, and *Cologne earth*. Some of the other colours may be occasionally useful, but these are all that are necessary for general use.

The best sort of water-colours are those mixed with gum and made up into cakes, as these may be used by rubbing upon a tile, in the same manner as Indian ink.

Mechanical Drawing.

We have given the name *mechanical drawing* to that sort of delineation which depends entirely on geometrical rules, and which is executed by the use of the ruler and compasses: such as the drawing of plans, elevations and sections of buildings, machinery, &c. This species of drawing is of very extensive utility, and is of so easy acquirement that it may be learned by every person in the same manner as writing.

For this purpose the geometrical problems should first be carefully and neatly drawn, and the hand should be accustomed to the use of the compasses and drawing-pen. Then the architectural mouldings should be studied, as they occur not only in buildings, but also in cabinet-work, machinery, and almost all kinds of implements.

In this kind of drawing the outlines of objects are laid down from actual measurement, by scales of equal parts; and the lines are drawn first with black lead pencil, and afterwards with ink, by means of the steel drawing-pen. The shadows also are added in Indian ink, and are drawn by rules that are established with mathematical precision.

OF THE MECHANICAL MEANS FOR COPYING DRAWINGS.

There are various methods by which those who are ignorant of the art of drawing may copy very accurately the outlines of pictures, prints, and drawings; and these methods are often useful to those who can draw, and to engravers, when either great expedition or great accuracy is required; though none of them should ever be used by one who is learning to draw.

Tracing against the Light.

Hold the drawing you wish to copy against one of the panes of the window; or have a pane of glass put in a frame, and fitted up like a music-stand, with a candle behind it. Lay your paper over your drawing, and you will see all the lines of the original distinctly through it, by which means you can easily trace them with a pen or black-lead pencil.

To make Tracing-Paper.

Mix together equal parts of oil of turpentine and drying-oil, and with a rag rub it evenly over some fan, or tissue paper, or any other very thin paper. Hang it by to dry for a day or two, and it will be fit for use. Lay this over the print or drawing you want to copy, and you will see every line distinctly through, so that you can go over them with the black-lead pencil. If you wish to do it in ink, you must mix a little ox's gall with the ink, to make the paper take it, which it would not otherwise do on account of the oil.

To make Camp-Paper.

Take some hard soap, mix it with lamp-black; make it into the consistence of a jelly with water; with this brush over one side of your paper, and let it dry. When you use it, put it between two sheets of clean paper, with its black side downwards, and with a pin, or stick with a sharp point, draw or write what you please upon the clean paper; and where the tracer has touched, there will be an impression upon the lowermost sheet of paper, as if it had been written or drawn with a pen. It may be made of any colour, by mixing with the soap black-lead, vermillion, &c.

Stenciling.

Lay the print or drawing you wish to have copied, over a sheet of paper, and with a pin or needle prick all the outline over with holes, through both the papers. Then take the clean paper with the holes made in it, and lay it upon the paper you wish to have the design transferred to, and dust it over with the powder of charcoal in a small muslin bag; the dust will penetrate through the holes, and leave a correct copy of the original upon the paper.

This pricked paper will do again for any number of copies. This is very useful for ladies who work flowers upon muslin.

The Method of Enlarging and Contracting by Squares.

Divide the sides of your original with a pair of compasses into any number of equal parts, and rule lines across with a black-lead pencil from side to side, and from top to bottom. Then having your paper of the size you intend, divide it into the same number of squares, either larger or less, as you would enlarge or contract it. Then placing your original before you, draw, square by square, the several parts, observing to make the part of the figure you are drawing fall in the same part of the squares in the copy, as it does in your original. To prevent mistakes, number the squares both of the original and copy. This method is much used by engravers.

To prevent the necessity of ruling across the original, which in some cases may injure it, take a square pane of crown glass, and divide its sides, and also its top and bottom into equal parts: then from each division draw lines across the glass with lamp-black ground with gum-water, and you will divide the glass into squares. Then lay the glass upon the original which you wish to copy, and having drawn the same number of squares upon your paper, proceed to copy into each square on your paper what appears behind each corresponding square of the glass. Instead of a glass, an open frame with threads stretched across will answer the same purpose.

The Pentagraph.

The Pentagraph is an instrument by means of which one may copy, enlarge, or reduce the outlines of any picture, print, or drawing. They may be had at most mathematical instrument-makers, and are extremely useful for copying plans, maps, and other complicated figures.

PAINTING TRANSPARENCIES.

The effect of this kind of painting is very pleasing, if managed with judgment, particularly in fire and moon lights, where brilliancy of light and strength of shade are so very desirable.

The very great expence attending the purchase of stained glass, and the risk of keeping it secure from accident, almost precludes the use of it in ornamenting rooms; but transparencies form a substitute nearly equal, and at a very small expence.

The paper upon which you intend to paint must be fixed in a straining-frame, in order that you may be able to place it between you and the light, when you see occasion in the progress of your work. After tracing in your design, the colours must be laid on in the usual method of stained drawings. When the tints are got in, you must place your picture against the window, on a pane of glass framed for the purpose, and begin to strengthen the shadows with Indian ink, or with colours, according as the effect requires, laying the colours sometimes on both sides of the paper, to give greater force and depth of colour. The last touches for giving final strength to shadows and forms, are to be done with ivory-black, or lamp-black prepared with gum-water, as there is no pigment so opaque and capable of giving strength and decision.

When the picture is finished, and every part has got its depth of colour and brilliancy, being perfectly dry, you touch very carefully with spirits of turpentine on both sides, those parts which are to be the brightest, such as the moon and fire, and those parts requiring less brightness, only on one side. Then lay on immediately with a pencil, a varnish made by dissolving one ounce of Canada balsam in an equal quantity of spirit of turpentine. You must be cautious with the varnish, as it is apt to spread. When the varnish is dry, you tint the flame with red-lead and gamboge, slightly tinging the smoke next the flame: the moon must not be tinted with colour.

Much depends upon the choice of the subject, and none is so admirably adapted to this species of effect as the gloomy Gothic ruin, whose antique towers and pointed turrets finely contrast their dark battlements with the pale, yet brilliant moon. Rays passing through the ruined windows half choaked with ivy, a fire amongst the clustering pillars and broken monuments of the choir, round which are figures of banditti, or others whose haggard faces catch the reflecting light, afford a peculiarity of effect, not to be equalled in any other species of painting. Internal views of cathedrals, also, where windows of stained glass are introduced, form beautiful subjects.

The great point to be attained is a happy coincidence between the subject and the effect produced. The fine light should not be too near the moon, as its glare would tend to injure her pale silver sight; those parts which are not interesting should be kept in an undistinguishable gloom, and where the principal light is, they should be marked with precision. Groups of figures should be well contrasted; those in shadow crossing those that are in light, by which means the opposition of light against shade is effected.

CRAYON-PAINTING.

If the limits of our work would have permitted us, we should have here said something respecting this branch of the art; but upon considering that it is a very inferior mode of painting, being only adapted for portraits, and being so perishable, that it is a pity the talents of any eminent artist should ever be employed in it, we have judged it better to suppress the article altogether, to make room for something of more importance. Those who are desirous of attempting it, may easily be furnished with the crayons ready prepared; and there is nothing particular in their use, which may not be easily acquired by any one who is acquainted with the practice of drawing.

COLOURS.

We shall now give a brief account of the different pigments or colours, which are used either in water or oil, for the purposes of drawing or painting.

Red Colours.

Lakes. This term is used to denote a species of colours formed by the combination of alumine, or the oxyd of tin, with the colouring matters of vegetables.

The lakes chiefly used are red colours, and these are of different qualities, according to the basis and colouring matter employed.

The principal lakes are *carmine*, *Florence-lake*, and *madder-lake*.

Carmine is a very rich bright crimson colour, and stands well in water. For the preparation of carmine, four ounces of finely-pulverized cochineal are to be poured into four or six quarts of rain, or distilled water, that has been previously boiled in a *pewter* kettle, and boiled with it for the space of six minutes longer (some advise to add, during the boiling, two drachms of pulverized crystals of tartar). Eight scruples of Roman alum, in powder, are to be then added, and the whole kept upon the fire one minute longer. As soon as the gross powder has subsided, and the decoction has become clear, it is to be carefully decanted into large cylindrical glasses, covered over, and kept undisturbod, till a fine powder is observed to have settled at the bottom. The liquor is then to be poured off from this powder, which is to be gradually dried. From the liquor, which is still much coloured, the rest of the colouring matter may be separated by means of the solution of tin, when it yields a carmine little inferior to the former.

Florentine lake is the kind in general use, known by the name of *lake*. It is used in water and also in oil, but does not stand, which is much to be lamented, as it is a very beautiful colour, and the is no substitute that will completely answer all the purposes of lake.

The best sort may be prepared from the sediment of cochineal that remains in the kettle after making carmine, adding to it a small quantity of cochineal, or Brazil-wood, and precipitating the colouring matter with a solution of tin.

Madder-lake is not so bright and rich a colour as the last-mentioned lakes, but has this valuable advantage, that it stands much better, and it may answer many of the purposes of Florence-lake.

It is prepared nearly in the same manner as the foregoing.

Rose-lake. This is generally called *rose-pink*. It is a lake made by a basis of chalk, coloured by Brazil or Campeachy wood. It does not stand, and is only used for house-painting and paper-hanging.

Vermillion, a bright scarlet pigment, formed from sulphur and quicksilver. Its goodness is known by its brightness, and by its inclining to a crimson hue. It is a very useful colour in oil, where it stands very well; but in water it is apt to turn black.

Red lead, or *minium*, is lead calcined till it acquires a red colour, by exposing it with a large surface to the fire. This colour is very apt to turn black in water, and is therefore seldom used.

Indian red. This colour is sometimes employed to answer some of the purposes of lake. It is difficult to procure the genuine kind, which comes from the East Indies. What is sold for Indian red, is said to be chiefly made in this country.

Venetian red is a native red ochre, rather inclining to the scarlet than the crimson hue: it is not far different in colour from the common Indian red, and is a very good colour.

Spanish-brown is also an earthy substance, found in the same state in which it is used; it is nearly of the same colour as Venetian red, but coarser. It is only used for the commonest purposes.

Light red, or *burnt ochre.* This is common yellow ochre heated red-hot in the fire, till the colour changes from yellow to a red. It is a very excellent colour, both in water and oil, having the quality in common with all the ochres, of standing perfectly well.

Red chalk. This is the same substance as is used for drawing on paper, in the manner of a crayon. It is very much like light red, and is used instead of it, for some purposes. It stands perfectly well, and may be used both in water and oil.

Burnt Terra Sienna. This colour is made by calcining raw terra Sienna till it acquires a red colour. It is of a very rich tint, and is much used both in water and oil. It stands well in both.

Blue Colours.

Ultramarine is prepared from *lapis lazuli,* by calcining and washing it very clean. When genuine, it is an extremely bright blue colour, somewhat transparent both in oil and water, and stands perfectly. On these accounts it is of the utmost value, being excellent in every kind of painting, even in enamel; but the great price prevents the general use of it.

Ultramarine ashes. This is the residuum after washing the lapis lazuli, in which a portion of the ultramarine still remains. It is very subject to be adulterated. It is not so bright as ultramarine, being, like that colour, with a tint of red and white in it. When genuine it stands well.

Prussian blue. This colour is iron combined with the prussic acid. It is made in the following manner.

Two parts of purified *potash* are most intimately blended with three parts of dried and finely pulverized *bullock's blood.* The mass is first calcined in a covered crucible, and on a moderate fire, until no more smoke or flame appear; and it is after this brought to a complete, yet moderate, ignition. Or equal parts of potash and finely-powdered coals, prepared from bones, horns, claws, &c. are mingled, and heated in a covered crucible to a moderate redness. This done, either of these two calcined masses is, after cooling, lixiviated with boiling water, and the lixivium filtered. Nothing remains now but to make a solution of one part of green vitriol and two parts of alum, and to add to it while yet hot the above lixivium, little by little however, and to separate the greenish-blue precipitate, which then forms by means of a filtre. If afterwards a slight quantity of diluted muriatic acid be affused upon this precipitate, it assumes a beautiful dark-blue colour. The operation is terminated by edulcorating and drying the pigment thus prepared. Prussian-blue is an extremely beautiful colour when properly prepared, and stands well. Common Prussian-blue is apt to contain some iron, which causes it to turn greenish or olive.

Verditer is a blue pigment, obtained by adding chalk or whitening to the solution of copper in aqua fortis. The best sort is prepared by the refiners, who employ for this purpose the solution of copper, which they obtain in the process of parting, by precipitating silver from aqua fortis by plates of copper. Common verditer is made from the sulphate of copper, or blue, by the manufacturers in Sheffield and Birmingham. Verditer is only used for very coarse purposes, chiefly by the paper-stainers. It has been sometimes called SANDERS blue, from ignorance of the meaning of the term *cendres blues*, or blue ashes, which the French call it.

Indigo. This colour is extracted from a plant called Anil, that grows in the East and West Indies. It is not so bright as Prussian-blue, but it is cooler, and has the advantage of being very durable. When dissolved by the sulphuric acid, it forms SCOTT'S *liquid blue*, so much used for colouring silk stockings, &c.

Smalt. This is glass coloured with cobalt, and ground to a fine powder. Its coarseness prevents its being used much for painting in oil or water. It is employed sometimes by sterwing it upon a ground of oil-paint. It is also used in enamel-painting. It stands well.

Blue Bice. This is only smalt more finely levigated.

Yellow Colours.

Indian yellow. This is the brightest of all yellows for water-colours, and is perfectly durable. It is said to be procured from the urine of the buffalo. In the East Indies it is a very common and cheap colour; the natives there use it commonly for colouring their calicoes, which they do without any mordant, so that the colour is washed out again when the cloth is dirty.

King's yellow. This colour is *orpiment* refined, which is a substance dug out of the earth, and consists of sulphur joined to arsenic; or it may be prepared by subliming sulphur with arsenic. It is of a very bright yellow, but does not stand very well; and great caution should be used in employing it, as it is a strong poison.

Naples yellow. This is a very durable and bright pale yellow; it comes from Naples, and is supposed to be prepared from lead and antimony.

Yellow ochre. This is an earth coloured by oxyd of iron. It is a cheap colour, and not very bright; but is valuable on account of its standing well.

Roman ochre. This is a superior kind of yellow ochre.

Dutch pink. This pigment is formed of chalk coloured with the juice of French berries, or other vegetables affording a yellow colour. It does not stand, and is chiefly used for common purposes.

Gamboge is a gum brought from the East Indies. It readily dissolves in water, and is a fine bright yellow. It is used only in water, and is very serviceable.

Massicot is an oxyd of lead, prepared by calcining white-lead. It is very little used, the colour not being very bright.

Gall stones. This is a concretion or hard substance, formed in the gall-bladders of beasts; or it may be obtained from the gall of animals. It is a very rich colour, but does not stand.

Raw Terra Sienna, is a native ochrous earth brought from Italy. It is a fine warm colour, and stands well.

French berries. A liquor may be extracted from these, which is useful as a stain for some coarse purposes; but it does not keep its colour.

Turmeric root, and *saffron*, may be used for similar purposes.

Orange lake is the tinging part of annatto precipitated together with the earth of alum. It does not stand.

Brown pink is the tinging part of some vegetable substance precipitated upon the earth of alum. It is of a fine rich greenish yellow, but does not stand in water.

Green Colours.

There are few colours that are useful as greens; accordingly, it is the practice with artists, to form their greens by the mixture of blue and yellow colours. By varying these, a vast variety of green tints may be obtained.

Sap green. This colour is the concreted juice of the buckthorn-berries. It is never used in oil. It is employed chiefly in flower-painting and colouring prints, &c.

Verdigris. If plates of copper, moistened from time to time with vinegar, be left exposed to the air, they will be converted into a green oxyd, called verdigris: this is an imperfect oxyd of copper, combined with a small portion of acetic acid, carbonic acid, and water. It is prepared in large quantities, chiefly in France near Montpellier, by stratifying copper-plates with the husks of grapes yet under vinous fermentation, which soon grow acid, and corrode the copper. After the plates have stood in this situation for a sufficient time, they are moistened with water, and exposed in heaps to the air. The verdigris is scraped off from their surface as it forms.

Verdigris is of a bluish-green colour, but has no body, and does not stand. It is only used for very coarse purposes. It answers best when used in varnishes.

Distilled verdigris, sometimes called crystals of verdigris, is prepared from common verdigris, by dissolving it in vinegar. It is of a very bright green, and is used chiefly for varnishes, and in colouring maps, &c.

Brown Colours.

Bistre is the finer part extracted from the soot of burnt wood. It is much used for sketches in water-colours, being a transparent warm colour.

Cologne earth. This is a mineral substance of a dark blackish brown colour. It is a very useful colour; though what is generally sold in the shops for Cologne earth is an artificial mixture of several colours.

Raw umbre is a native ochreous earth, of a light brown. It stands well.

Burnt umbre. This is only the last mentioned colour, calcined in the fire. It then acquires a rich deep brown, and is of great use, being a fine colour, and standing perfectly well.

Asphaltum. This colour is used in oil, and is of a very rich deep brown. It is a transparent or glazing colour. It will not work in water, but when dissolved in turpentine, it becomes a useful substance for giving deep and spirited touches to drawings.

White Colours.

Flake White is corbonate of lead, formed by corroding lead with vegetable acids, or vinegar.

White-lead is the same colour as flake white, only of an inferior quality. It is the only white used in oil-painting, and is a very useful colour; but in water it always turns black, and should never be used.

Pure carbonate of lime is very useful as a white in water-colours, as it stands perfectly well.

Egg-shell white, and *oyster-shell white*, are only egg-shells, or oyster-shells calcined, by which the animal gluten is destroyed, leaving the lime behind, which soon attracts the carbonic acid again from the atmosphere. Well washed *Spanish white*, or *common whitening*, answers the same purpose.

Black Colours.

Lamp black is the soot of oil, collected after it is formed by burning. It is very generally used, both in oil and water, and stands perfectly well.

Ivory black is the coal of ivory or bone, formed by giving them a great heat, while they are deprived of all access of air. It is of a more intense black than lamp black.

Blue black is the coal from burning vine-stalks in a close vessel. It is like ivory black, with a tint of blue.

Indian ink has been already described in page 346.

OF ENGRAVING.

Engraving, or *graving*, as it is sometimes called, is the cutting lines upon a copper-plate, by means of a steel instrument, called a graver.

This was the first way of producing copper-plate prints that was practised, and is still much used in historical subjects, portraits, and in finishing landscapes.

The tools necessary for this art are, gravers, a scraper, a burnisher, an oil-stone, a sand-bag, an oil-rubber, and some good charcoal.

The gravers are instruments of tempered steel, fitted into a short wooden handle. They are of two sorts, square and lozenge: the first is used in cutting very broad strokes, the other for fainter and more delicate lines.

The scraper is a three-edged tool, for scraping off the burr raised by the graver. Burnishers are for rubbing down any lines that are too deep, or burnishing out any scratches or holes in the copper: they are of very hard steel, well rounded and polished.

The oil-stone is for whetting the gravers, etching-points, &c.

The sand-bag, or cushion, is for laying the plate upon, for the conveniency of turning it round in any direction.

The oil-rubber and charcoal are for polishing the plate when necessary.

As great care is required to whet the graver nicely, particularly the belly of it, the two angles of the graver which are to be held next the plate, must be laid flat upon the stone, and rubbed steadily, till the belly rises gradually above the plate, so as that, when you lay the graver flat upon it, you may just perceive the light under the point; otherwise it will dig into the copper, and then it will be impossible to keep a point, or execute the work with freedom. In order to this, keep your right arm close to your side, and place the fore-finger of your left hand upon that part of the graver which lies uppermost on the stone. When this is done, in order to whet the face, place the flat part of the handle in the hollow of your hand, with the belly of the graver upwards, upon a moderate slope, and rub the extremity, or face, upon the stone, till it has an exceedingly sharp point, which you may try upon your thumb-nail.

When the graver is too hard, as is usually the case when first bought, and which may be known by the frequent breaking of the point, the method of *tempering* it is as follows: Heat a poker red-hot, and hold the graver upon it, within half an inch of the point, till the steel changes to a light straw colour; then put the point into oil, to cool; or hold the graver close to the flame of a candle, till it be of the same colour, and cool it in the tallow; but be careful either way, not to hold it too long, for then it will be too soft; and in this case the point, which will then turn blue, must be tempered again. Be not too hasty in tempering; for sometimes whetting will bring it to a good condition, when it is but a little too hard.

To hold the graver, cut off that part of the handle which is upon the same line with the belly, or sharp edge of the graver, making that side flat, that it may be no obstruction.

Hold the handle in the hollow of your hand; and, extending your fore-finger towards the point, let it rest on the back of the graver, that you may guide it flat and parallel with the plate. Take care that your fingers do not interpose between the plate and the graver; for they will hinder you from carrying the graver level with the plate, and from cutting your strokes so clean as they ought to be.

To lay the design upon the plate, after you have polished it fine and smooth, heat it so that it will melt virgin-wax, with which rub it thinly and equally over, and let it cool. Then the design which you lay on must be drawn on paper, with a black-lead pencil, and laid upon the plate, with its pencilled side upon the wax; press it down, and with a burnisher go over every part of the design, and when you take off the paper, you will find every line upon the waxed plate which you drew with the black lead pencil; then with a sharp pointed tool trace all your design through the wax upon the plate, and you may then take off the wax, and proceed to work.

Let the table, or board you work at, be firm and steady; upon which place your sand-bag with the plate upon it; and, holding the graver as above directed, proceed in the following manner.

For straight strokes, hold your plate firm upon the sand-bag with your left hand, moving your right hand forwards; leaning lighter where the stroke should be fine, and harder where you would have it broader.

For circular or crooked strokes, hold the graver stedfast, moving your hand or the plate, as you see convenient.

Learn to carry your hand with such dexterity, that you may end your stroke as finely as you began it; and if you have occasion to make one part deeper or blacker than another, do it by degrees; and that you may do it with greater exactness, take care that your strokes be not too close nor too wide.

In the course of your work scrape off the roughness which arises, with your scraper; but be careful, in doing this, not to scratch the plate; and that you may see your work properly as you go on, rub it with the oil-rubber, and wipe the plate clean, which will take off the glare of the copper, and show what you have done to the best advantage.

Any mistakes or scratches in the plate may be rubbed out with the burnisher, and the part levelled with the scraper, polishing it again afterwards lightly with the burnisher, or charcoal.

Having thus attained the use of the graver, according to the foregoing rules, you will be able to finish the piece you had etched, by graving up the several parts to the colour required; beginning, as in the etching, with the fainter parts, and advancing gradually with the stronger, till the whole is completed.

The dry point or needle (so called because not used till the ground is taken off the plate) is principally employed in the extremely light parts of water, sky, drapery, architecture, &c.

To prevent any obstruction from too great a degree of light, the use of a sash, made of transparent, or fan paper, pasted on a frame, and placed sloping at a convenient distance between your work and the light, will preserve the sight; and when the sun shines, it cannot possibly be dispensed with.

ETCHING.

Etching is a manner of engraving on copper, in which the lines or strokes, intead of being cut with a tool or graver, are corroded in with aqua fortis.

It is a much later invention than the art of engraving by cutting the lines on the copper, and has many advantages over it for some purposes, though it cannot supersede the use of the graver entirely, as there are many things that cannot be etched so well as they can be graved.

In almost all the engravings on copper that are executed in the stroke manner, etching and graving are combined, the plate being generally begun by etching, and finished with the graver. Landscapes, architecture, and machinery, are the subjects that receive most assistance from the art of etching; for it is not so applicable to portraits and historical designs.

We shall first describe the various instruments and materials used in the art.

Copper-plates may be had ready prepared at the coppersmiths, by those who reside in large towns; but when this cannot be had, procure a piece of pretty thick sheet-copper from a brazier, rather larger than your drawing, and let him planish it well; then take a piece of pumice-stone, and with water rub it all one way, till the surface is as smooth and level as it can be made by that means: a piece of charcoal is next used with water, for polishing it still farther, and removing the deep scratches made by the pumice-stone; and it is then finished with a piece of charcoal of a finer grain, with a little oil.

Etching-points or *needles* are pointed instruments of steel, about an inch long, fixed in handles of hard wood, about six inches in length, and of the size of a goose-quill. They should be well tempered, and very accurately fixed in the centre of the handle. They must be brought to an accurately conical point, by rubbing upon an *oil-stone*, with which it is also very necessary to be provided. Several of these points will be necessary.

A *parallel-ruler* is necessary for drawing parallel straight lines with. This is best when faced with brass, as it is not then so liable to be bruised by accident.

Compasses are useful for striking circles and measuring distances.

Aqua fortis, or what is better, spirits of nitre, (nitrous acid,) is used for corroding the copper, or *biting*-in, as it is called. This must be kept in a bottle with a glass stopple, for its fumes destroy corks. A stopple made of wax will serve as a substitute, or a cork well covered with wax.

Bordering-wax, for surrounding the margin of the copper-plate when the aqua fortis is pouring on. This may be bought ready prepared, but it may be made as follows.

Take one-third of bees-wax to two-thirds of pitch; melt them in an iron ladle, and pour them, when melted, into water lukewarm; then mould it with your hand till it is thoroughly incorporated, and all the water squeezed out. Form it into rolls of convenient size.

Turpentine varnish is used for covering the copper-plate with, in any part where you do not wish the aqua fortis to bite. This may be diluted to a proper consistence with turpentine, and mixed with lamp-black, that it may be seen better when laid upon the plate.

Ectching-ground is used for covering the plate all over with, previous to drawing the lines on it with the needles. It is prepared in the following manner.

Take of virgin-wax and asphaltum, each two ounces, of black pitch and Burgundy pitch, each half an ounce; melt the wax and pitch in a new earthenware glazed pipkin, and add to them, by degrees, the asphaltum, finely powdered. Let the whole boil till such time as that, by taking a drop upon a plate, it will break when it is cold, on bending it double two or three times between the fingers. The varnish, being then enough boiled, must be taken off from the fire, and letting it cool a little, must be poured into warm water, that it may work the more easily with the hands, so as to form into balls for use.

It must be observed, first, that the fire be not too violent, for fear of burning the ingredients; a slight simmering will be sufficient; secondly, that while the asphaltum is putting in, and even after it is mixed with them, the ingredients should be stirred continually with a spatula; and thirdly, that the water into which this composition is thrown, should be nearly of the same degree of warmth with it, to prevent a kind of cracking, which happens when the water is too cold.

The varnish ought always to be harder in summer than winter, and it will become so if it be suffered to boil longer, or if a greater proportion of the asphaltum be used. The experiment above mentioned, of the drop suffered to cool, will determine the degree of hardness or softness that may be suitable to the season when it is used.

To lay the ground for etching, proceed in the following manner: Having cleaned the copper-plate with some fine whiting and a linen rag, to free it from all grease, fix a hand-vice to some part of it where no work is intended to be, to serve as a handle for managing it by when warm. Roll up some coarse brown paper, and light one end; then hold the back of the plate over the burning paper, moving it about until every part of it is equally heated, so as to melt the etching-ground, which should be wrapped up in a bit of taffety, to prevent any dirt that may happen to be among it, from mixing with what is melted upon the plate. If the plate be large, it will be best to heat it over a chafing-dish with some clear coals. It must be heated just sufficient to melt the ground, but not so much as to burn it. When a sufficient quantity of the etching-ground has been rubbed upon the plate, it must be dabbed, or beat gently, while the plate is hot, with a small dabber, made of cotton, wrapped up in a piece of taffety, by which operation the ground is distributed more equally over the plate than it could be by any other means.

When the plate is thus uniformly and thinly covered with the varnish, it must be blackened by smoking it with a wax taper. For this purpose twist together three or four pieces of wax taper, to make a larger flame, and while the plate is still warm, hold it with the varnished side downwards, and move the smoky part of the lighted taper over its surface, till it is made almost quite black; taking care not to let the wick touch the varnish, and that the latter get no smear or stain. In laying the etching-ground, great care must be taken that no particles of dust or dirt of any kind settle upon it, as that would be found very troublesome in etching; the room, therefore, in which it is laid should be as still as possible, and free from dust.

The ground being now laid, and suffered to cool, the next operation is to transfer the design to the plate.

For this purpose a tracing on oiled paper must now be made, from the design to be etched, with pen and ink, having a very small quantity of ox's gall mixed with it, to make the oiled paper take it; also a piece of thin paper, of the same size, must be rubbed over with red chalk, powdered, by means of some cotton. Then laying the red chalked paper, with its chalked side next the ground, on the plate, put the tracing over it, and fasten them both together, and to the plate, by a little bit of the bordering wax.

When all this is prepared, take a blunt etching needle, and go gently all over the lines in the tracing; by which means the chalked paper will be pressed against the ground, and the lines of the tracing will be transferred to it: on taking off the papers, they will be seen distinctly.

The plate is now prepared for drawing through the lines which have been marked upon the ground. For this, the etching-points or needles are employed, leaning hard or lightly, according to the degree of strength required in the lines. Points of different sizes and forms are also used, for making lines of different thickness, though commonly this is effected by the biting-in with the aqua fortis.

A margin or border of wax must now be formed all round the plate, to hold the aqua fortis when it is poured on. To do this, the bordering wax already described must be put into lukewarm water to soften it, and render it easily worked by the hand. When sufficiently pliable, it must be drawn out into long rolls, and put round the edges of the plate, pressing it down firm, and forming it with the fingers into a neat wall or margin. A spout must be formed in one corner, to pour off the aqua fortis by afterwards.

The nitrous acid (spirits of nitre) is now to be diluted with four or five times as much water, or more (according as you wish the plate to be bit quick or slow,) and poured upon the plate. In a few minutes you will see minute bubbles of air filling all the lines that have been drawn on the copper, which are to be removed by a feather; and the plate must be now and then *swept*, as it is called, or kept free from air bubbles. By the more or less rapid production of these bubbles, you judge of the rapidity with which the acid acts upon the copper. The biting-in of the plate is the most uncertain part of the process, and nothing but very great experience can enable any one to tell when the plate is bit enough, as you cannot easily see the thickness and depth of the line till the ground is taken off.

When you judge, from the time the acid has been on, and the rapidity of the biting, that those lines which you wish to be the faintest are as deep as you wish, you pour off the aqua fortis by the spout, wash the plate with water, and dry it, by blowing with bellows, or by the fire, taking care not to melt the ground.

Those lines that are not intended to be bit any deeper, must now be stopped up with turpentine-varnish mixed with a little lamp-black, and laid on with a camel's-hair pencil; and when this is thoroughly dry, the aqua fortis may be poured on again, to bite the other lines that are required to be deeper.

This process of stopping-out and biting-in is to be repeated as often as there are to be lines of different degrees of thickness, taking care not to make any mistake in stopping-out wrong lines.

It is also necessary to be particularly careful to stop-out with the varnish, those parts from which the ground may happen to have come off by the action of the acid, otherwise you will have parts bit that were not intended, which is called *foul-biting*.

When the biting-in is quite finished, the next operation is to remove the bordering-wax and the ground, in order that you may see what success you have had; for till then, this cannot be known exactly.

To take off the bordering-wax, the plate must be heated by a piece of lighted paper, which softens the wax in contact with the plate, and occasions it to come off quite clean.

Oil of turnpentine is now poured upon the ground, and the plate is rubbed with a bit of linen rag, which removes all the ground. Lastly, it is cleaned off with whitening.

The success of the etching may now be known, but it is necessary to get an impression taken upon paper by a copper-plate printer. This impression is called a *proof*.

If any parts are not bit so deep as were intended, the process may be repeated, provided the lines are not too faintly bit to admit of it. This second biting-in the same lines, is called *re-biting*, and is done as follows: Melt a little of the etching-ground on a spare piece of copper, and dab it a little, to get some on the dabber; then, having cleaned out, with whiting, the lines that are to be re-bit, heat the plate gently, and dab it very lightly with the dabber. By this, the parts between the lines will be covered with the ground, but the lines themselves will not be filled up, and consequently will be exposed to the action of the aqua fortis. This is a very delicate process, and must be performed with great care. The rest of the plate must now be varnished over, the bordering wax put on again, and the biting repeated in the same manner as at first.

If any part should be bit too deep, it is more difficult to recover it, or make it fainter: this is generally done by burnishing the part down, or rubbing it with a piece of charcoal. This will make the lines shallower, and cause them not to print so black.

Should any small parts of the lines have missed altogether in the biting, they may be cut with the graver; which is also sometimes employed to cross the lines of the etching, and thus to work up a more finished effect.

Dry-pointing is another method employed for softening the harsh effects usually apparent in an etching. This is done by cutting with the etching-point upon the copper without any ground or varnish, which does not make a very deep line, and is used for covering the light, where very delicate tints and soft shadows are wanting. By varying these processes of etching, graving, and dry-pointing, as is thought necessary, the plate is worked up to the full effect intended; and it is then sent to the writing engraver, to grave whatever letters may be required to be put upon it.

MEZZOTINTO SCRAPING.

This art is of later origin than the last, and is not of such difficult execution. In mezzotinto prints the shadows are not formed by lines or hatches, but much resemble Indian ink. It differs in the process, however, from aquatinta, although the effect is not very different.

Mezzotinto is chiefly employed in portraits and historical subjects; and aqua tinta for landscape and architecture.

The tools necessary for mezzotinto scraping are the grounding-tool, burnishers, and scrapers.

To lay the mezzotinto ground, lay your plate, with a piece of flannel under it, upon your table; hold the grounding-tool in your hand perpendicularly; lean upon it moderately hard, continually rocking your hand in a right line from end to end, till you have wholly covered the plate in one direction: next cross the strokes from side to side, afterwards from corner to corner, working the tool each time all over the plate, in every direction, almost like the points of a compass; taking all possible care not to let the tool cut (in one direction) twice in a place. This done, the plate will be full, or, in other words, all over rough alike, and would, if it were printed, appear completely black.

Having laid the ground, take the scrapings of black chalk, and with a piece of rag rub it over the plate; or you may smoke it with candles, as before directed, for etching.

Now take your drawing, and having rubbed the black with red chalk-dust, mixed with flake-white, proceed to trace it on the plate.

To form the lights and shadows, take a blunt needle, and mark out the outlines only, then with a scraper scrape off the lights in every part of the plate, as clean and smooth as possible, in proportion to the strength of the lights in your drawing, taking care not to hurt your outlines.

The use of the burnisher is to soften or rub down the extreme light parts after the scraper is done with; such as the tip of the nose, forehead, linen, &c. which might otherwise, when proved, appear rather misty than clear.

Another method used by mezzotinto scrapers, is, to etch the outlines of the original, as also the folds in drapery, making the breadth of the shadows by dots, which having bit to a proper depth with aqua fortis, they take off the ground used in etching, and having laid the mezzotinto ground, proceed to scrape as above.

When your plate is ready for taking a proof or impression, send it to the copper-plate printer, and get it proved. When the proof is dry, touch it with white chalk where it should be lighter, and with black chalk where it should be darker; and when the print is retouched, proceed as before, for the lights; and for the shades use a small grounding-tool, as much as you judge necessary to bring it to a proper colour; and when you have done as much as you think expedient, prove it again; and so proceed to prove and touch till it is entirely to your mind.

AQUA TINTA.

Aqua-tinta is a method of producing prints very much resembling drawings in Indian-ink.

The principle of the process consists in corroding the copper with aqua fortis, in such a manner, that an impression from it has the appearance of a tint laid on the paper. This is effected by covering the copper with a powder, or some substance which takes a granulated form, so as to prevent the aqua fortis from acting where the particles adhere, by this means causing it to corrode the copper partially, and in the interstices only. When these particles are extremely minute and near to each other, the impression from the plate appears to the naked eye exactly like a wash of Indian-ink; but when they are larger, the granulation is more distinct; and as this may be varied at pleasure, it is capable of being adapted with great success, to a variety of purposes and subjects.

This powder, or granulation, is called the *aqua-tinta grain*, and there are two general modes of producing it.

We shall first describe what is called the *powder-grain*, because it was the first that was used.

Having etched the outline on a copper-plate, prepared in the usual way by the coppersmith (for which see the article etching), some substance must be finely powdered and sifted, which will melt with heat, and when cold will adhere to the plate, and resist the action of aqua fortis. The substances which have been used for this purpose, either separately or mixed, are *asphaltum*, *Burgundy-pitch*, *rosin*, *gum-copal*, *gum-mastich*; and in a greater or less degree, all the resins and gum-resins will answer the purpose. Common rosin has been most generally used, and answers tolerably well; though gum-copal makes a grain that resists the aqua fortis better.

The substance intended to be used for the grain must now be distributed over the plate as equally as possible; and different methods of performing this essential part of the operation have been used by different engravers, and at different times.

The most usual way is to tie up some of the powder in a piece of muslin, and strike it against a piece of stick held at a considerable height above the plate; by this, the powder that issues falls gently, and settles equally over the plate. Every one must have observed how uniformly hair-powder settles upon the furniture after the operations of the hair-dresser. This may afford a hint towards the best mode of performing this part of the process. The powder must fall upon it from a considerable height, and there must be a sufficiently large cloud of the dust formed. The plate being covered equally over with the dust, or powder, the operator is next to proceed to fix it upon the plate, by heating it gently, so as to melt the particles. This may be effected by holding under the plate lighted pieces of brown paper, rolled up, and moving them about till every part of the powder is melted; this will be known by its change of colour, which will turn brownish. It must now be suffered to cool, when it may be examined with a magnifier, and if the grains or particles appear to be uniformly distributed, it is ready for the next part of the process.

The design or drawing to be engraved must now be examined, and such parts of it as are perfectly white are to be remarked. Those corresponding parts of the plate must be covered, or stopped out (as it is called) with turpentine-varnish, diluted with turpentine to a proper consistence to work freely with the pencil, and mixed with lamp-black to give it colour; for if transparent, the touches of the pencil would not be so distinctly seen. The margin of the plate must also be covered with varnish. When the stopping out is sufficiently dry, a border of wax must be raised round the plate, in the same manner as in etching, and the aqua fortis properly diluted with water poured on. This is called biting in, and is the part of the process which is most uncertain, and which requires the greatest degree of experience. When the aqua fortis has lain on so long that the plate, when printed would produce the lightest tint in the drawing, it is poured off, and the plate washed with water, and dried. When it is quite dry, the lightest tints in the drawing are stopped out, and the aqua fortis poured on as before, and the same process is repeated as often as there are tints to be produced in the plate.

Although many plates are etched entirely by this method of stopping out and biting in alternately, yet it may easily be conceived, that in general, it would be very difficult to stop round, and leave out all the finishing touches, as also the leaves of trees and many other objects, which it would be impossible to execute with the necessary degree of freedom, in this manner.

To overcome this difficulty, another very ingenious process has been invented, by which these touches are laid on the plate with the same ease and expedition as they are in a drawing in Indian-ink. Fine washed whiting is mixed with a little treacle or sugar, and diluted with water in the pencil, so as to work freely, and this is laid on the plate covered with the aqua-tint ground, in the same manner, and on the same parts as ink on the drawing. When this is dry, the whole plate is varnished over with a weak and thin varnish of turpentine, asphaltum, or mastich, and then suffered to dry, when the aqua fortis is poured on. The varnish will immediately break up in the parts where the treacle mixture was laid, and expose all those places to the action of the acid, while the rest of the plate remains secure. The effect of this will be, that all the touches or places where the treacle was used will be bit in deeper than the rest, and will have all the precision and firmness of touches in Indian-ink.

After the plate is completely bit in, the bordering-wax is taken off, by heating the plate a little with a lighted piece of paper; and it is then cleared from the ground and varnish by oil of turpentine, and wiped clean with a rag and a little fine whiting, when it is ready for the printer.

The principal disadvantages of this method of aqua-tinting are, that it is extremely difficult to produce the required degree of coarseness or fineness in the grain, and that plates so engraved do not print many impressions before they are worn out. It is therefore now very seldom used, though it is occasionally of service.

We next proceed to describe the second method of producing the aqua-tint ground, which is generally practised. Some resinous substance is dissolved in spirits of wine, as common resin, Burgundy-pitch, or mastich, and this solution is poured all over the plate, which is then held in a slanting direction, till the superfluous fluid drains off; and it is then laid down to dry, which it does in a few minutes. If the plate be then examined with the magnifier, it will be found that the spirit, in evaporating, has left the resin in a granulated state, or rather, that the latter has cracked in every direction, still adhering firmly to the copper.

A grain is thus produced with the greatest ease, which is extremely regular and beautiful, and much superior for most purposes to that produced by the former method. After the grain is formed, every part of the process is conducted in the same manner as above described.

Having thus given a general idea of the art, we shall mention some particulars necessary to be attended to, in order to ensure success in the operation. The spirits of wine used for the solution, must be highly rectified, and of the best quality. What is sold in the shops generally contains camphor, which would entirely spoil the grain. Resin, Burgundy-pitch, and gum mastich, when dissolved in spirits of wine, produce grains of a different appearance and figure, and are sometimes used separately, and sometimes mixed in different proportions, according to the taste of the artist, some using one substance, and some another. In order to produce a coarser or finer grain, it necessary to use a greater or smaller quantity of resin; and to ascertain the proper proportions, several spare pieces of copper must be provided, on which the liquid may be poured, and the grain examined, before it is applied to the plate to be engraved. After the solution is made, it must stand still and undisturbed for a day or two, till all the impurities of the resin have settled to the bottom, and the fluid is quite pellucid. No other method of freeing it from those impurities has been found to answer; straining it through linen or muslin, only fills it with hairs, which are ruinous to the grain. The room in which the liquid is poured on the plate must be perfectly still and free from dust, which, whenever it falls on the plate while wet, causes a white spot, which it is impossible to remove without laying the grain a-fresh. The plate must also be previously cleaned, with the greatest possible care, with a rag and whiting, as the smallest stain or particle of grease produces a streak or blemish in the grain. All these attentions are absolutely necessary to produce a tolerably regular grain; and, after every thing that can be done by the most exprienced artists, still there is much uncertainty in the process. They are sometimes obliged to lay on the grains several times, before they procure one sufficiently regular. The same proportions of materials do not always produce the same effect, as it depends in some degree on their qualities: and it is even materially altered by the weather. These difficulties are not to be surmounted but by a great deal of experience; and those who are daily in the habit of practising the art are frequently liable to the most unaccountable accidents. Indeed, it is much to be lamented, that so elegant and useful a process should be so extremely delicate and uncertain.

It being necessary to hold the plate in a slanting direction, in order to drain off the superfluous fluid, there will naturally be a greater body of the liquid at the bottom than at the top of the plate. On this account, a grain laid in this way is always coarser at the side of the plate that was held lowermost. The most usual way is, to keep the coarsest side for the fore-ground, that being generally the part which has the deepest shadows. In large landscapes, sometimes various parts are laid with different grains, according to the nature of the subject.

The finer the grain is, the more nearly does the impression resemble Indian-ink, and the fitter it is for imitating drawings: but very fine grains have several disadvantages; for they are apt to come off before the aqua fortis has lain on long enough to produce the desired depth; and as the plate is not corroded so deep, it soon wears out in printing; whereas coarser grains are firmer, the acid goes deeper, and the plate will throw off a great many more impressions. The reason of all this is evident, when it is considered, that in the fine grains, the particles are small and near each other, and consequently the aqua fortis, which acts laterally as well as downwards, soon undermines the particles, and causes them to come off. If left too long on the plate, the acid would eat away the grain entirely.

On these accounts, therefore, the moderately coarse grains are more sought after, and answer better the purpose of the publisher, than the fine grains which were formerly in use.

Although there are considerable difficulties in laying properly the aqua tint grain, yet the corroding the copper, or biting-in, so as to produce exactly the tint required, is still more precarious and uncertain. All engravers allow that no positive rules can be laid down, by which the success of this process can be secured; nothing but a great deal of experience and attentive observation can enable the artist to do it with any degree of certainty.

There are some hints, however, which may be of considerable importance to the person who wishes to attain the practice of this art. It is evident, that the longer the acid remains on the copper, the deeper it bites, and consequently the darker will be the shade in the impression. It may be of some use, therefore, to have several bits of copper laid with aqua tint grounds, of the same kind to be used in the plate, and to let the aqua fortis remain for different lengths of time on each; and then to examine the tints produced in one, two, three, four minutes, or longer. Observations of this kind, frequently repeated, and with different degrees of strength of the acid, will at length assist the judgment, in guessing at the tint which is produced in the plate. A magnifier is also useful to examine the grain, and to observe the depth to which it is bit. It must be observed, that no proof of the plate can be obtained till the whole process is finished. If any part appears to have been bit too dark, it must be burnished down with a steel burnisher; but this requires great delicacy and good management not to make the shade streaky; and as the beauty and durability of the grain is always somewhat injured by it, it should be avoided as much as possible.

Those parts which are not dark enough must have a fresh grain laid over them, and be stopped round with varnish, and subjected again to the aqua fortis. This is called re-biting, and requires peculiar care and attention. The plate must be very well cleaned out with turpentine before the grain is laid on, which should be pretty coarse, otherwise it will not lay upon the heights only, as is necessary, in order to produce the same grain. If the new grain is different from the former, it will not be so clear nor so firm, but rotten.

We have now given a general account of the process of engraving in aqua tint, and we believe that no material circumstance has been omitted, that can be communicated without seeing the operation; but after all it must be confessed, that no printed directions whatever can enable a person to practise it perfectly. Its success depends upon so many niceties, and attention to circumstances apparently trifling, that the person who attempts it must not be surprised if he does not succeed at first. It is a species of engraving simple and expeditious, if every thing goes on well; but it is very precarious, and the errors which are made are rectified with great difficulty.

It seems to be adapted chiefly for imitation of sketches, washed drawings, and slight subjects; but does not appear to be at all calculated to produce prints from finished pictures, as it is not susceptible of that accuracy in the balance of tints necessary for this purpose. Nor does it appear to be very suitable for book-plates, as it does not print a sufficient number of impressions. It is, therefore, not to be put in competition with other modes of engraving. If confined to those subjects for which it is calculated, it must be allowed to be extremely useful, as it is expeditious, and may be attained with much less trouble than any other mode of engraving. But even this circumstance is a source of mischief, as it occasions the production of a multitude of prints that have no other effect than that of vitiating the public taste.

Engraving in aqua tint was invented by Le Prince, a French artist, who kept his process a long time secret, and it is said he sold his prints at first as drawings; but he appears to have been acquainted only with the powder-grain and the common method of stopping-out. The prints which he produced are still some of the finest specimens of the art. Mr. Paul Sandby was the first who practised it in this country, and it was by him communicated to Mr. Jukes. It is now practised very generally all over Europe; but no where more successfully than in this kingdom.

WOOD-CUTTING.

Wood-cutting or engraving on wood is a process exactly the reverse to engraving on copper. In the latter, the strokes to be printed are sunk, or cut into the copper, and a rolling-press is used for printing it; but in engraving on wood, all the wood is cut away, except the lines to be printed, which are left standing up like types, and the mode of printing is the same as that used in letter-press.

The wood used for this purpose is box-wood, which is planed quite smooth. The design is then drawn upon the wood itself with black-lead, and all the wood is cut away with gravers and other proper tools, except the lines that are drawn. Or sometimes the design is drawn upon paper, and pasted upon the wood, which is cut as before. This art is of considerable difficulty, and there are few who practise it. It is, however, useful for books, as the printing of it is cheaper than that of copper-plates. It cannot be applied equally well to all the purposes to which copper-plate engraving is applicable.

ETCHING ON GLASS.

Glass resists the action of all the acids, except the fluoric acid. By this, however, it is corroded in the same manner as copper is by aqua fortis; and plates of glass may be engraved in the same manner as copper.

There are several methods of performing this. We shall first describe the mode of etching by means of the fluoric acid in the *state of gas*. Having covered over the glass to be etched with a thin coat of virgin-wax (which is only common bees-wax bleached white,) draw the design upon it, in the same manner as in etching on copper. Then take some *fluor spar*, commonly called *Derbyshire spar*, pound it fine, and put it into a leaden vessel, pouring some sulphuric acid over it. Place the glass with the etched side lowermost over this vessel, two or three inches above it. Apply a gentle heat to the leaden vessel; this will cause the acid to act upon the fluor spar, and disengage the gas, which will corrode the glass. When it is sufficieutly corroded, remove the wax by oil of turpentine.

This etching may be also performed by raising a margin of bordering-wax all round the glass, in the same manner as on copper, and pouring on the liquid fluoric acid, which acts upon the glass. The method of making this acid was described under the article fluoric acid, in chemistry.

A third method of etching on glass is as follows: Having put the wax on the glass, draw your design, and raise a margin all round it. Then put pounded fluor spar, with some sulphuric acid diluted with water, upon the glass. The sulphuric acid will disengage the fluoric, which will be absorbed by the water, and corrode the glass.

In all the above-mentioned methods, some of the gas is let loose in the apartment, and is exceedingly suffocating. To remedy this inconvenience, an apparatus was contrived by the editor of this work, some years ago, and is found to answer perfectly.

A, Fig. 5., Plate XVII., Vol. 1., is a cylindrical leaden vessel, having a rim B all round it, made like Count Rumford's steam rim for cooking vessels, into which is put a little water. Into this rim fits a cover *c*, having a pipe *d* coming from it, which is inserted into a large oblong vessel *e* of sheet lead, or iron well tinned, having a rim and cover similar to the vessel A, only the cover has no aperture. The fluate of lime powdered and the sulphuric acid are put into the leaden vessel A, which is placed upon a stand made of wire, having a lamp to heat the contents of the vessel over it. As soon as the gas is evolved it ascends, and not being able to escape through the rim B, on account of the water, which condenses a portion, it proceeds through the tube into the large vessel *e*, in which is placed, upon stands of wire, the glass prepared for etching by drawing through a varnish, as above described.

In this vessel the gas collects, and acts upon the glass: the rim with water prevents any noxious fumes from escaping into the room. The vessel *e* is placed upon a stand of such a height as to agree with that of the lamp. In this manner the process may be conducted with the utmost ease and elegance.

Beautiful ornaments may thus be etched on glass, and applied to decorate windows, by painting the figure of the ornament on panes of glass with enrgravers' stopping varnish, and then exposing the panes to the action of the gass in the vessel *e*. The gas will corrode all the surface of the glass, except where the varnish has been put, and give it much the appearance of ground glass, which may be rendered more or less opaque by lengthening or shortening the process. The parts where the varnish was applied will continue transparent and seem extremely bright. It is to be noticed, when the liquid fluoric acid is used, the lines which have been etched continue still transparent; but when the gas has been employed, the line is white and opaque, as if cut by a wheel.

LITHOGRAPHY.

This art is so called, because the impressions are produced from drawings made on *stone*. It was invented by Aloys Sennefelder, a German, about the year 1800.

There are several styles of drawing employed in lithographic prints. The chief are, the line manner, and the chalk manner. In the line manner, which is similar in its effect to the line engraving on copper of second rate quality, lines are drawn on a stone with a particular sort of ink, by means of pens of various kinds, or a camels-hair pencil.

In both these methods, the same kind of stone is used; but in the line manner, the stone must be polished smooth with pumice-stone, whereas, for the chalk it is made a little rough, by grinding with sand. The stone must be calcareous and of a light colour. The white lias in this country answers tolerably well, but is not so fit as the German stones.

The lithographic ink is composed of equal parts of tallow, bees-wax, shell lac, and common soap, with a sufficient quantity of lamp-black to colour it. These ingredients are mixed by heating them, and even burning them in an iron vessel. When cold, the mass is rubbed on a tile with water, like Indian ink, and put into a pen or brush.

The lithographic chalk is formed of 2 oz. of tallow, 2½ oz. of bees-wax, 1 oz. of shell lac, and 1½ oz. of common soap. These are also united by heating as before; when cold it is cut into slips, and used as a crayon.

When the drawing is made on the stone with the pen and ink, or with the chalk or crayon, some water, having in it a little nitric acid, is poured over the stone, which slightly corrodes the surface; gum-water is then laid on with a brush, and the stone is left to dry; it is now ready for printing from.

To print from the stone, the printer proceeds to wet the surface of it with a sponge with water, and then applies the printing ink, by a roller.

The printing ink, made of equal parts of burnt oil or varnish, and lamp-black, sometimes with the addition of wax and tallow, adheres to the lines which have been drawn with the lithographic ink on the stone, while the water prevents it from sticking to the rest of the surface. The lines alone are thus charged with printing ink. Some damped paper is now laid upon the stone, and passed through a press, by which an impression is obtained. The stone is again wetted, and the printing ink applied for a second impression, and so on.

The process is the same for printing chalk drawings; but they are more difficult to print, and give fewer impressions.

This art has made considerable progress on the continent; in this country it has advanced more slowly, chiefly from the secresy employed in the processes of printing. On this account, its advantages were not well comprehended, it being difficult to institute a just comparison between this and the other species of engraving, which are in this country carried to such a high degree of perfection. It is now, however, rapidly improving, since artists have been induced to take it up, and we shall probably soon equal, if not surpass, our continental neighbours.

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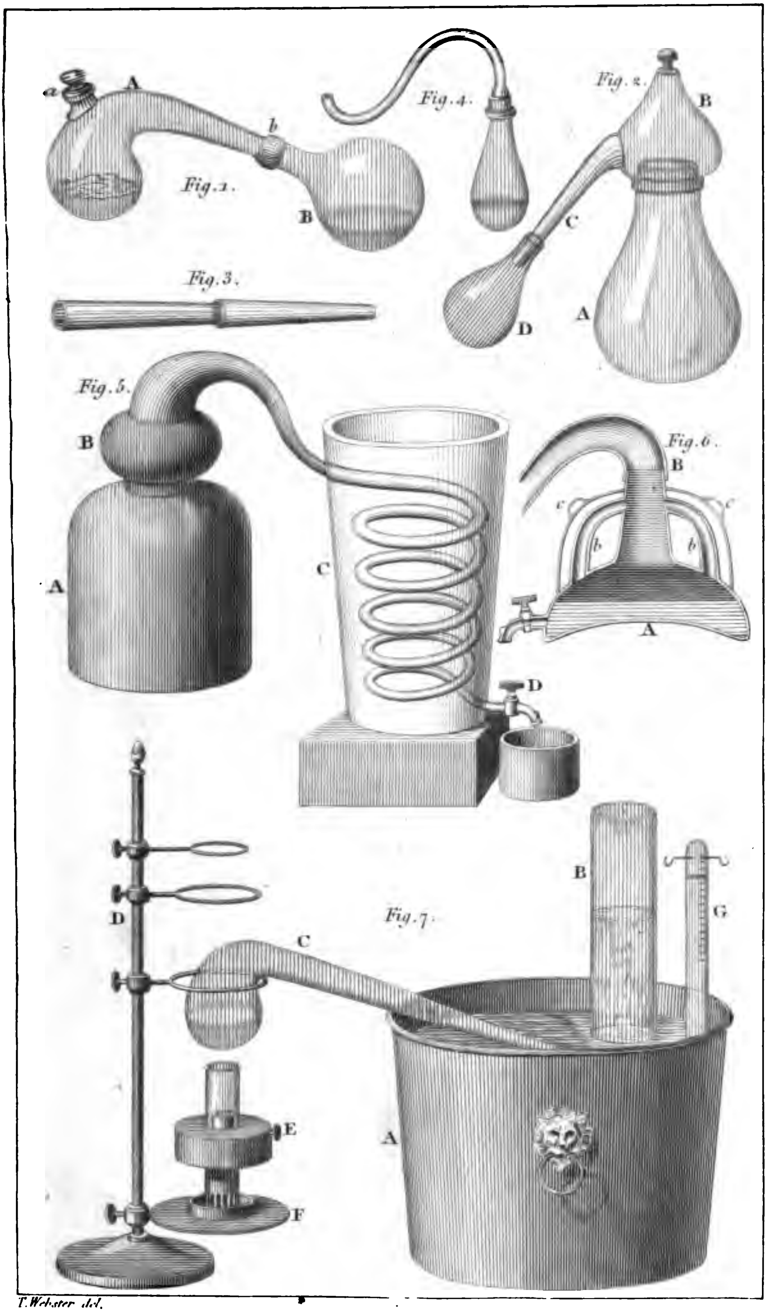

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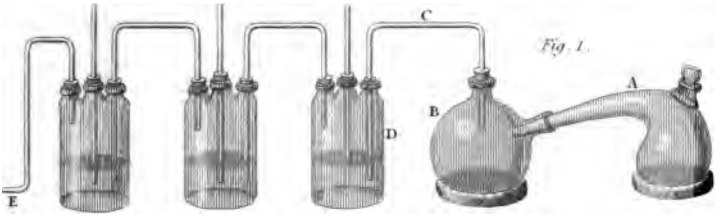

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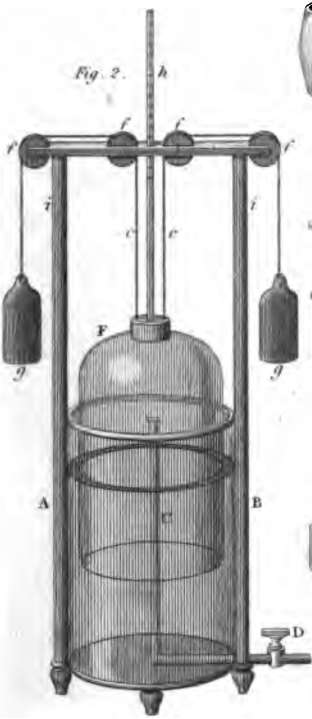

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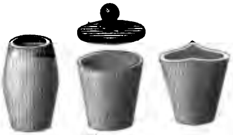

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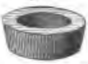

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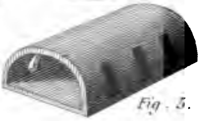

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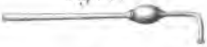

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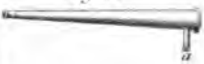

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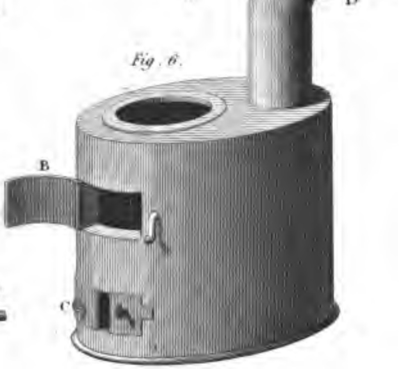

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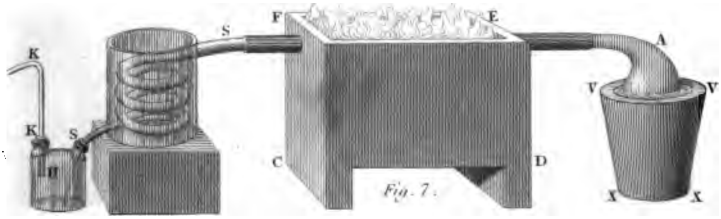

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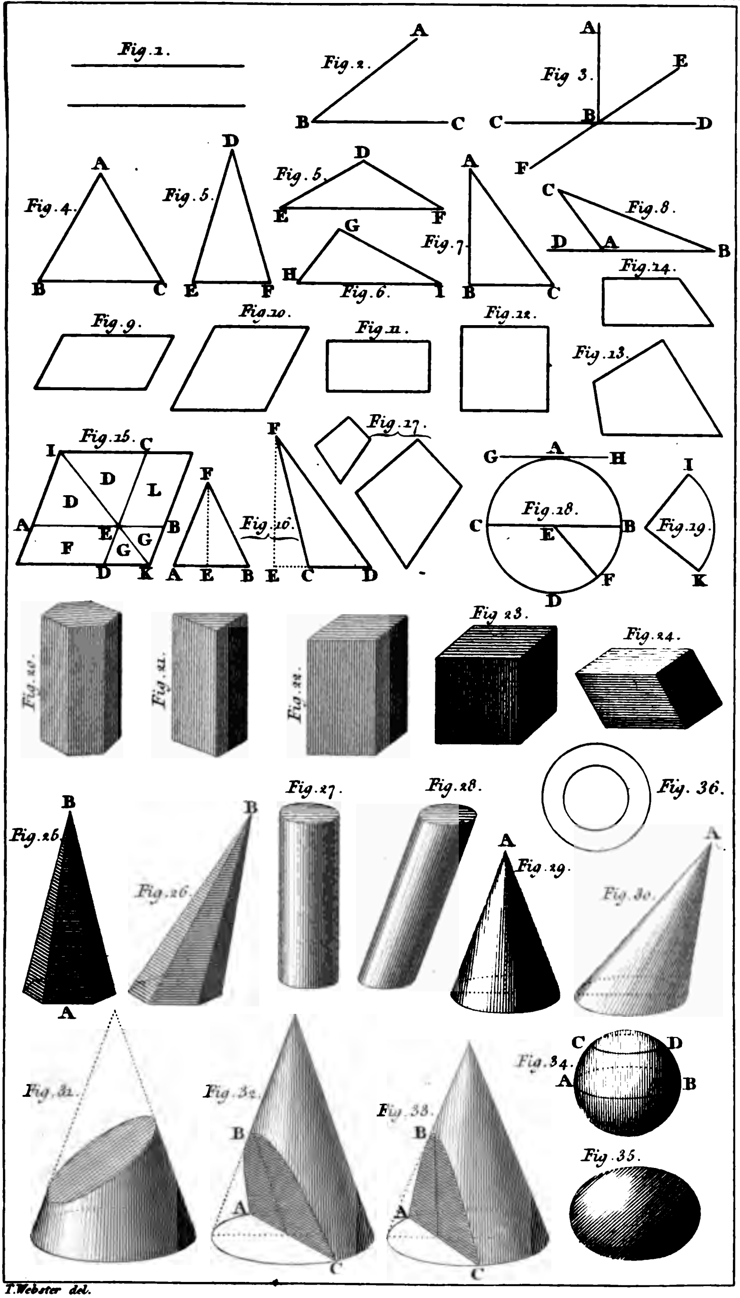

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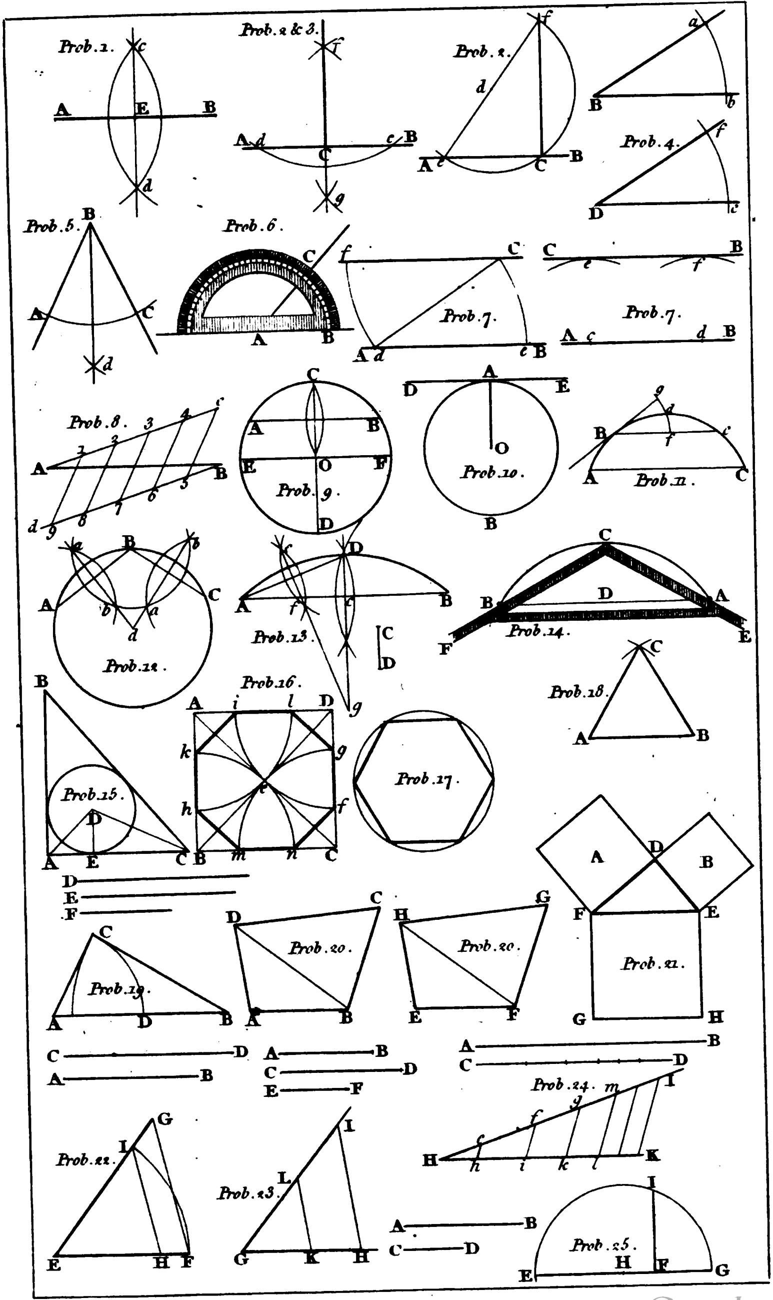

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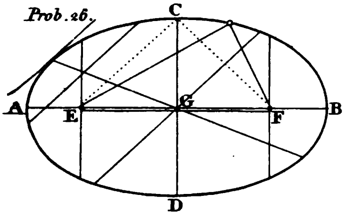

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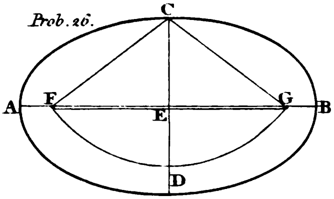

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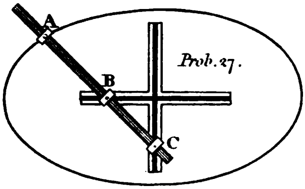

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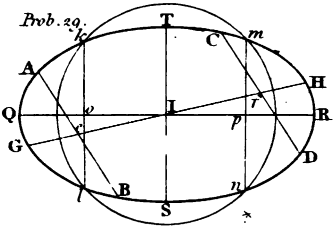

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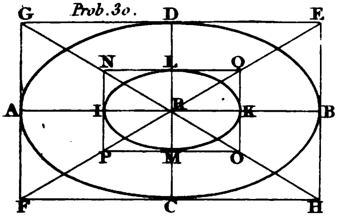

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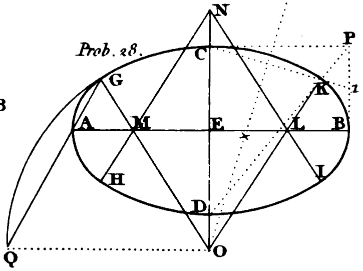

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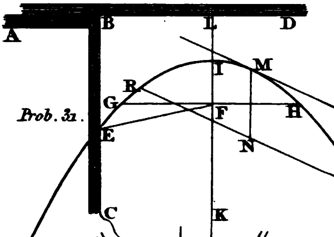

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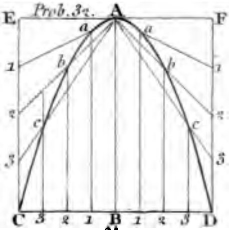

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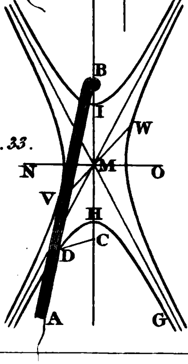

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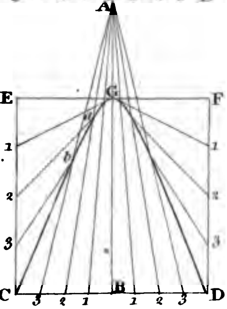

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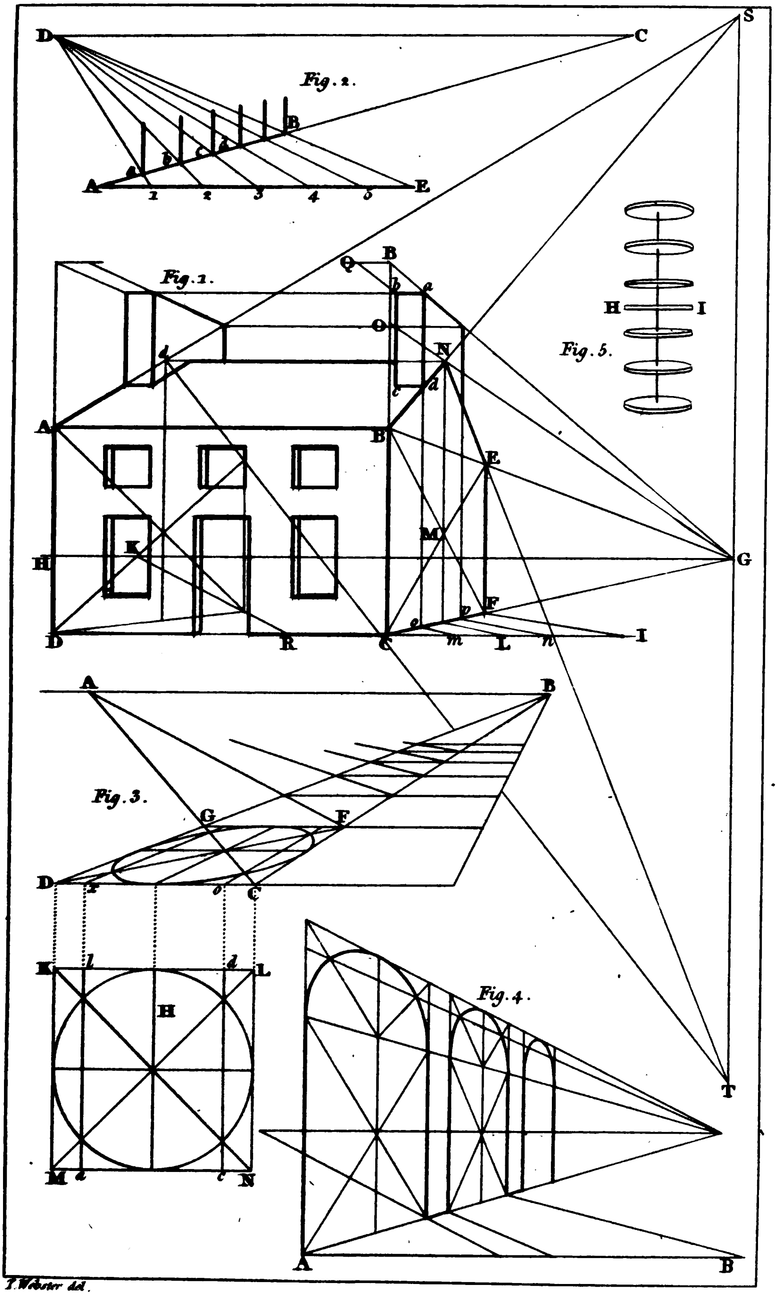

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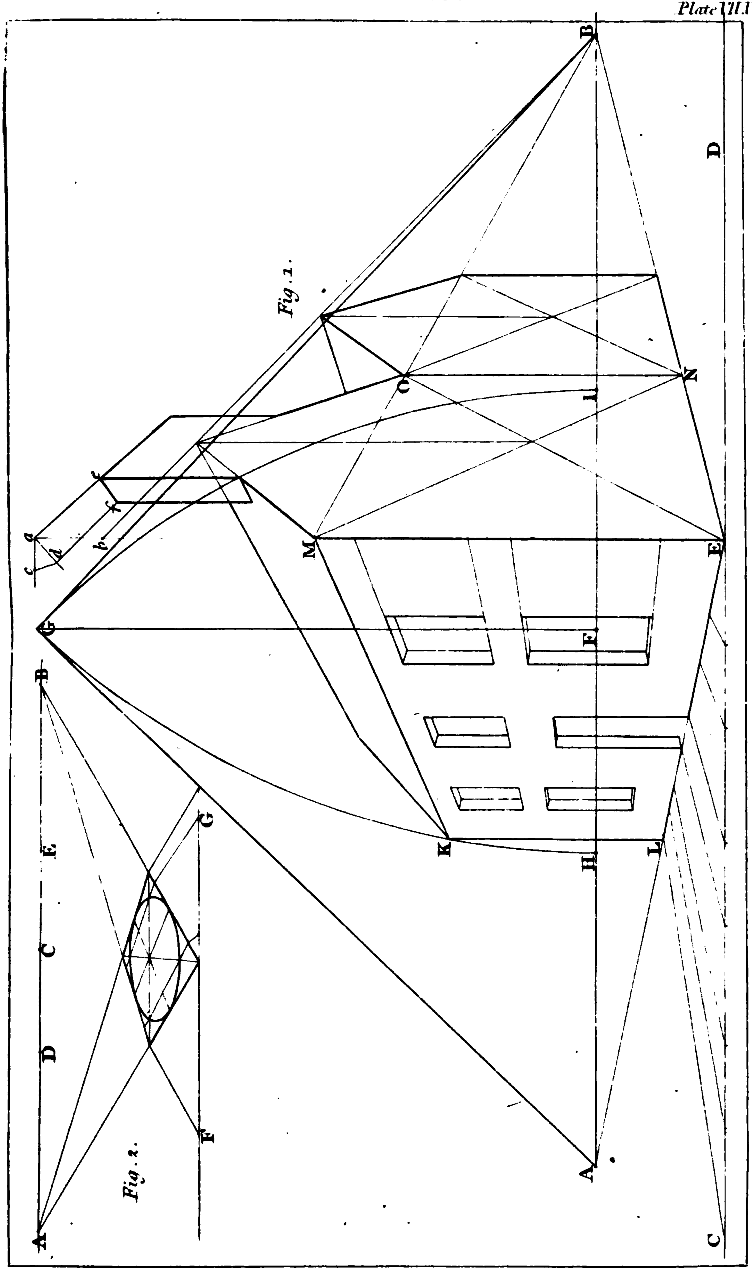

Fig. 1.

Fig. 2.

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